

FINAL

**Long-Term Monitoring
Quarterly Groundwater Report
Area of Concern A**

Prepared For

**81 CES /CEVR
Keesler Air Force Base, Mississippi**



**Air Education and Training Command
Randolph Air Force Base, Texas**

Contract No. F41689-96-D-0710

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Prepared By

**PARSONS ENGINEERING SCIENCE, INC.
Atlanta, Georgia**

January 2000

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**FINAL
LONG-TERM MONITORING
QUARTERLY GROUNDWATER REPORT
AREA OF CONCERN A**

PREPARED FOR:

**81 CES / CEVR
KEESLER AIR FORCE BASE, MISSISSIPPI
AIR EDUCATION AND TRAINING COMMAND
RANDOLPH AIR FORCE BASE, TEXAS**

**CONTRACT NO. F41689-96-D-0710
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5390 TRIANGLE PARKWAY
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TABLE OF CONTENTS

	Page
SECTION 1 INTRODUCTION.....	1-1
1.1 Purpose.....	1-1
1.2 Site History.....	1-1
1.3 Project Events.....	1-3
SECTION 2 MONITORING WELL GAUGING AND SAMPLING RESULTS.....	2-1
2.1 Monitoring Well Gauging.....	2-1
2.2 Groundwater Sampling and Analytical Results	2-1
2.3 Field Determined Parameters.....	2-2
SECTION 3 SAMPLE COLLECTION PROCEDURES AND QUALITY ASSURANCE/QUALITY CONTROL	3-1
3.1 Sample Collection.....	3-1
3.1.1 Groundwater Sampling and Handling.....	3-1
3.2 Quality Assurance/Quality Control.....	3-2
SECTION 4 POTENTIAL RECEPTORS AND MIGRATION PATHWAYS	
4.1 Potential Exposure Pathways.....	4-1
4.1.1 Surface Water Receptor Pathways	4-1
4.1.2 Soil Hydrocarbon Receptor Pathways	4-1
4.1.3 Groundwater Receptor Pathways	4-2
4.2 Water-Supply Well Survey.....	4-2
SECTION 5 CONTAMINANT ATTENUATION ASSESSMENT.....	5-1
5.1 Introduction	5-1
5.2 Evidence of Contaminant Biodegradation Over Time	5-1
5.2.1 Hydrocarbon Concentration Trends in Soil	5-1
5.2.2 Hydrocarbon Concentration Trends in Groundwater	5-2
5.3 Evidence of Contaminant Biodegradation Via Microbially Mediated Redox Reactions	5-2
5.3.1 Dissolved Oxygen	5-3
5.3.2 Ammonia	5-3
5.3.3 Ferrous Iron	5-3
5.3.4 Sulfate	5-3
5.3.5 Dissolved Methane	5-3
5.4 Theoretical Assimilative Capacity Estimates.....	5-4
5.5 Summary of Findings	5-4

TABLE OF CONTENTS (CONTINUED)

SECTION 6	CONCLUSIONS AND RECOMMENDATIONS	6-1
6.1	Conclusions	6-1
6.2	Recommendations	6-1
SECTION 7	REFERENCES	7-1
APPENDIX A	LABORATORY DATA	
APPENDIX B	GROUNDWATER SAMPLING RECORDS	
APPENDIX C	DATA VALIDATION SUMMARY	
APPENDIX D	CONTAMINANT ATTENUATION ASSESSMENT	

LIST OF FIGURES

No.	Title
1.1	Location of Keesler AFB, Mississippi
1.2	Site Location Map
1.3	Monitoring Well Location Map
2.1	Potentiometric Surface Map – June 1999
2.2	Groundwater Analytical Results
2.3	BTEX Distribution in Groundwater
4.1	Groundwater Wells Relative to AOC A

LIST OF TABLES

No.	Title
2.1	Summary of Monitoring Well Gauging Data
2.2	Groundwater Analytical Results
2.3	Initial Groundwater Screening Summary
4.1	Keesler AFB Water Supply Wells

SECTION 1 INTRODUCTION

1.1 PURPOSE

This report documents the results of a quarterly groundwater sampling event performed in June 1999 at Area of Concern A (AOC A) at Keesler Air Force Base (AFB) in Biloxi, Mississippi (Figure 1.1). The data in this report will be used to evaluate the current extent and attenuation potential of hydrocarbon contamination in the groundwater at AOC A. Facility 1504 (AAFES Service Station) lies adjacent to AOC A and these sites were studied as one due to the presence of commingled hydrocarbon plumes. Quarterly groundwater monitoring is being performed at AOC A to fulfill a Resource Conservation and Recovery Act (RCRA) requirement and is approved by the United States Environmental Protection Agency (USEPA) and the Mississippi Department of Environmental Quality (MDEQ). The location of AOC A is shown on Figure 1.2. Figure 1.3 illustrates the layout of AOC A and monitoring well locations.

1.2 SITE HISTORY

AOC A (also known as the BX Service Station) is located at Larcher Boulevard and Meadows Drive. The station is currently active and includes service bays and pump islands. Underground storage tanks (USTs) containing gasoline and diesel fuel are located at the western portion of the site. These tanks currently meet federally mandated upgrade requirements for UST systems and have not leaked. In 1987, Environmental Science & Engineering (ESE) removed 10 USTs used to store automotive gasoline. Six of the tanks were located along the eastern side of Building 1504, and four were located just south of the building. Physical evidence, such as stained soils and high organic vapor readings, observed during the excavation showed that one or more of the tanks had leaked in the past [Engineering-Science, Inc. (ES) (now Parsons ES), 1994]. Previous investigation activities have included:

Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA): In September 1987, a RCRA Facility Assessment report for Keesler AFB was prepared (A.T. Kearney, Inc. *et al.*, 1987). This report identified all Solid Waste Management Units (SWMUs) at the Base, as well as other AOCs. Related information from a file review and a visual site inspection were used to assess the potential for contamination and to determine what further measures, if any, should be taken to safeguard human health and the environment. The BX Service Station was determined to be an AOC.

Site Characterization Under the Installation Restoration Program (IRP): A field effort for a site characterization of Keesler AFB was initiated by ESE under the IRP in November 1987 (ESE, 1991), and the results are reported in the final site characterization report dated January 1991. This effort was performed in three sampling

events in November and December 1987, April 1988, and October and November 1989. During the 1987 removal of 10 USTs at the BX Service Station, 16 soil samples were collected and analyzed for TPH and inorganic extraction procedure (EP) toxicity. Analysis of soil gas samples collected in the excavation area indicated a hydrocarbon anomaly adjacent to the east-northeast side of the service station. Based on this information, five monitoring wells (MW8-1 through 8-5) were installed at the site to evaluate potential groundwater contamination. Groundwater samples were collected from these wells in 1988 and 1989. The BX Service Station was identified as Site 8 in the ESE (1991) report.

RCRA Facility Investigation (RFI): ES performed an RFI in 1992 to assess the horizontal and vertical extent of contamination in soil and groundwater (Parsons ES, 1999). Soil contamination at AOC-A was defined through installation of 13 soil borings and associated soil sampling. Eight additional monitoring wells (MWA-6 through MWA-13) were installed at the site to monitor for possible free floating product on the groundwater surface, and to determine the lateral extent of the dissolved hydrocarbon contamination. The site was further characterized by performing a soil organic vapor survey in which BTEX, carbon dioxide, and oxygen concentrations were determined for each soil gas sample.

Well Assessment Report: A Well Assessment Report was produced by BCM Environmental Inc. (BCM) in September 1996. This report summarizes the location, construction, and condition of the 13 monitoring wells at AOC A. Five of the monitoring wells were reported to be in fair condition. The remaining eight wells were in good condition (BCM, 1996).

Previous and current interim remedial actions include:

Bioventing: In April 1993, initial testing was conducted for a bioventing system, and six shallow vent wells (three extraction wells and three injection wells) were installed in the vicinity of the former USTs by Battelle-Columbus, Inc. (Battelle). The bioventing system was initiated on May 21, 1993. Confirmatory soil and soil gas samples were collected after one year of operation. Average TPH concentrations in vadose zone soils were reduced by 78 percent and average TPH concentrations in soil gas were reduced by 89 percent as compared to initial concentrations (Battelle, 1995).

Density-Driven Convection (DDC) In-Well Aeration System: Wasatch Environmental, Inc. (WEI) performed a large-scale test of a DDC in-well aeration system at AOC-A. The system, which includes 32 DDC wells, 6 soil vapor extraction wells, and three blowers, began operating on May 9, 1996. The primary objective of the DDC system was to reduce saturated zone soil contamination because the previous bioventing system had already reduced vadose zone soil concentrations. A draft final report was submitted to USEPA and MDEQ on November 21, 1997 (WEI, 1997). Results of

preliminary confirmatory soil sampling indicate a significant decrease in soil total petroleum hydrocarbons (TPH) in the 7-10 feet below ground surface (bgs) interval.

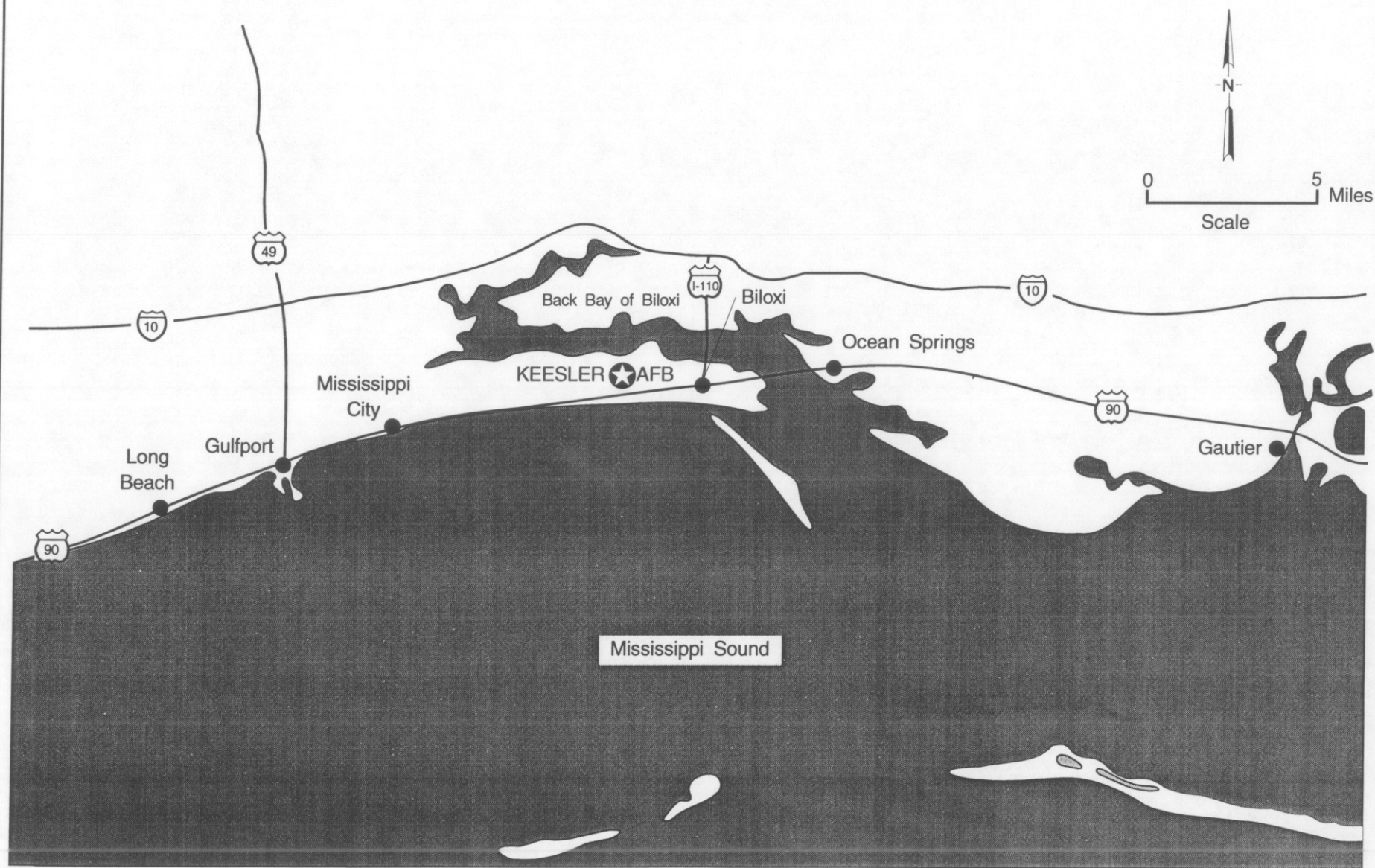
1.3 PROJECT EVENTS

Groundwater sampling was conducted at AOC A on June 22-24, 1999. Nine wells were sampled and included MW8-1, MW8-3, MW8-4, MW8-5, MWA-7, MWA-8, MWA-9, MWA-11, and MWA-13.

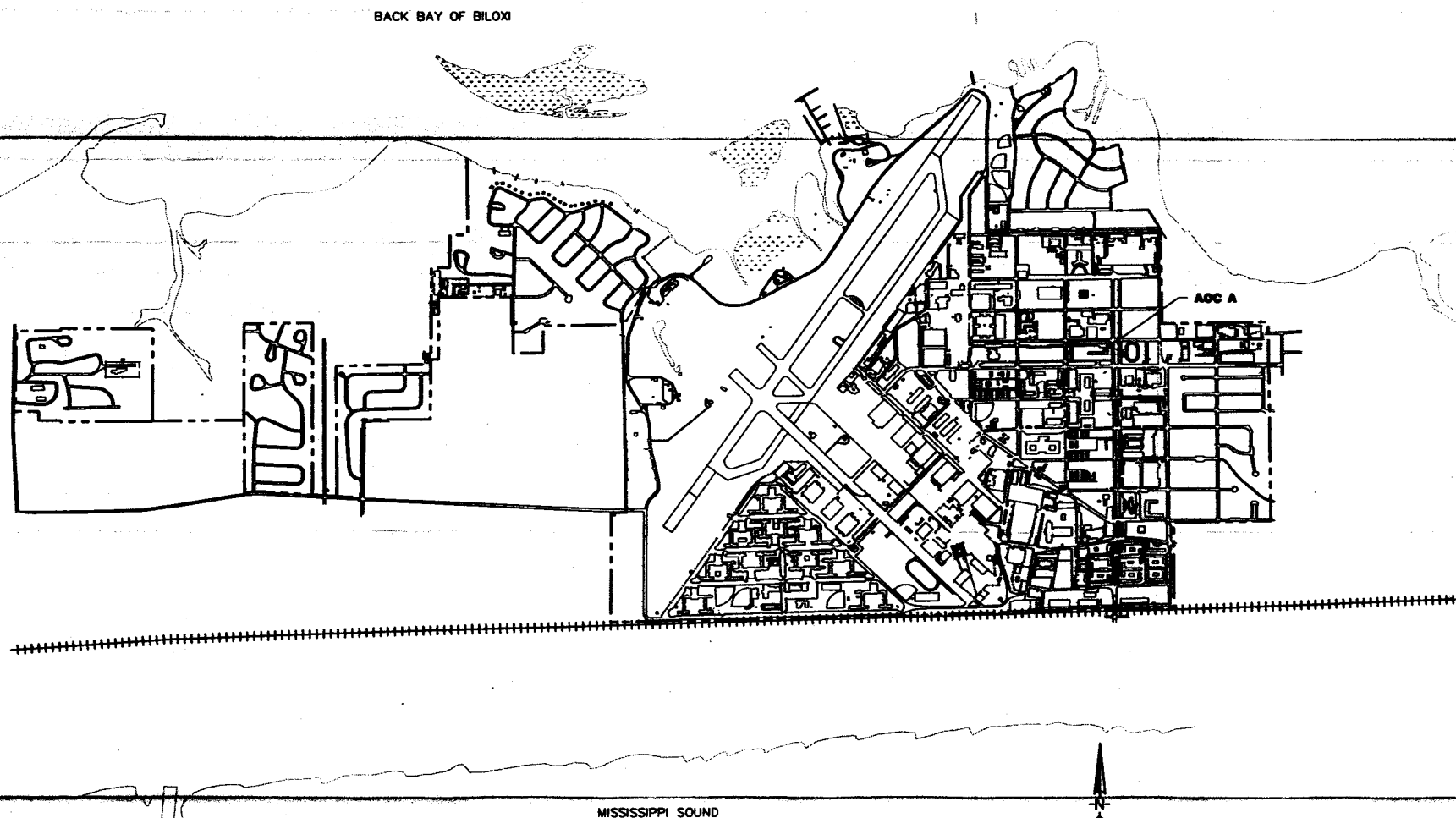
Activities completed during the June 1999 sampling event included the following:

- A peristaltic pump and a Horiba U-10 water quality meter were utilized to purge the wells and obtain field parameters characterizing the groundwater from the surficial aquifer.
- Measurements of monitoring well groundwater levels were recorded to develop a potentiometric surface map of groundwater elevations and determine groundwater flow direction.
- Collection of quarterly groundwater samples from the monitoring wells for analysis of benzene, toluene, ethylbenzene, xylenes (BTEX), methyl-tertiary-butylether (MTBE), ammonia, methane, ferrous iron, and sulfate analyses in support of a natural attenuation evaluation.
- A survey of all wells was completed to obtain elevations for constructing groundwater potentiometric maps.

Figure 1.1
Location of Keesler AFB, Mississippi

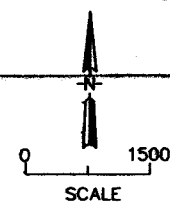


Source: Commercial Road Map

**SITE LOCATION MAP - AOC A
KEESLER AIR FORCE BASE
BILOXI, MISSISSIPPI****LEGEND**

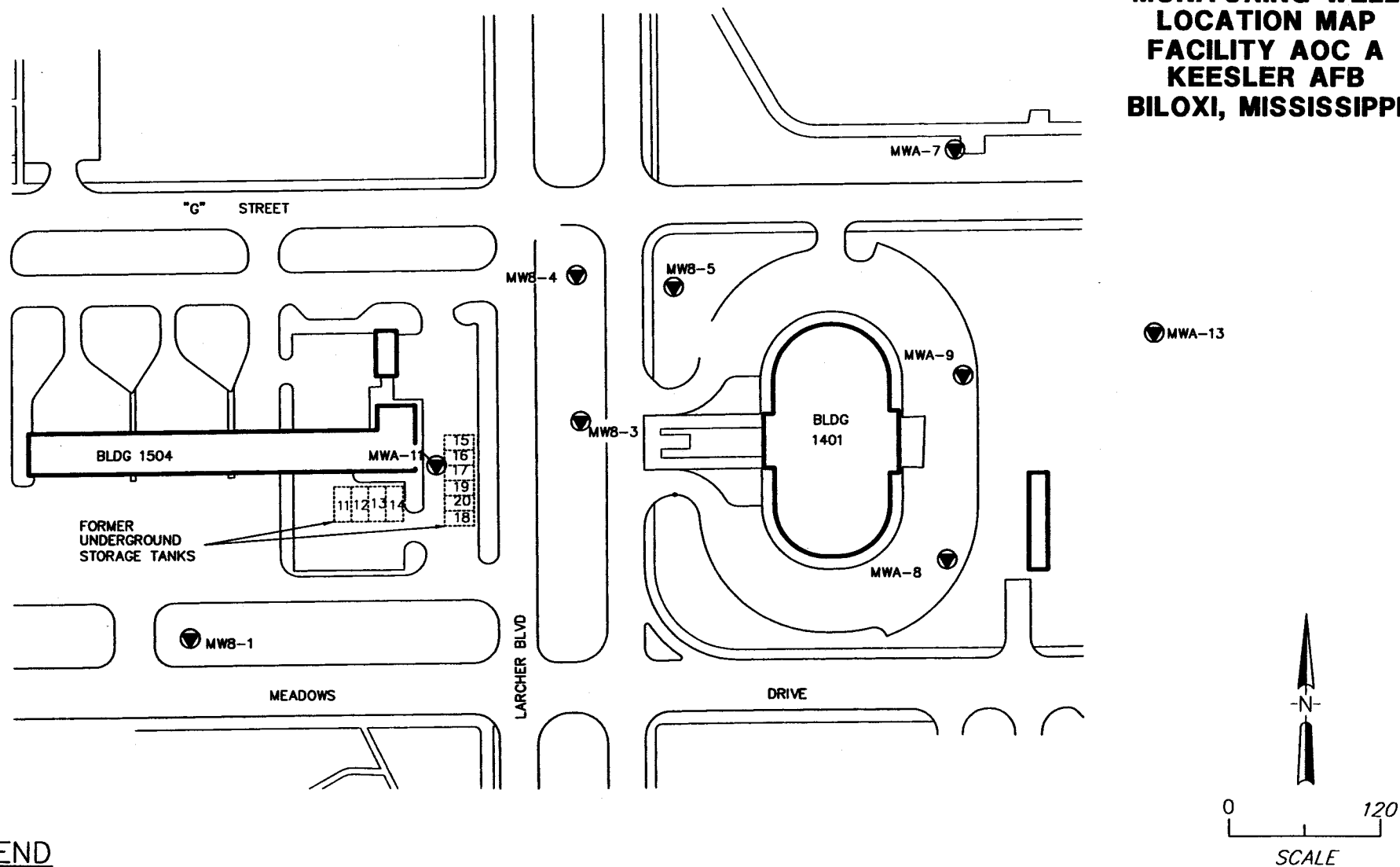
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**FIGURE 1.3
MONITORING WELL
LOCATION MAP
FACILITY AOC A
KEESLER AFB
BILOXI, MISSISSIPPI**



LEGEND

● MONITORING WELL



SECTION 2 MONITORING WELL GAUGING AND SAMPLING RESULTS

2.1 MONITORING WELL GAUGING

Groundwater level measurements were recorded at AOC A and Facility 1504 on June 23, 1999 and are provided in Table 2.1. Depth to water ranged from 6.86 to 10.43 feet below top of well casing. A potentiometric surface map was prepared based on these measurements and is provided as Figure 2.1. Groundwater flow at the site is generally toward the east.

2.2 GROUNDWATER SAMPLING AND ANALYTICAL RESULTS

The monitoring wells at AOC A were sampled on June 22-24, 1999. Groundwater samples were collected from monitoring wells MW8-1, MW8-3, MW8-4, MW8-5, MWA-7, MWA-8, MWA-9, MWA-11, and MWA-13. The samples were analyzed for BTEX, MTBE, and methane by an off-site laboratory. In addition, on site analysis for ammonia, sulfate, and ferrous iron was conducted to determine the natural attenuation capacity of the surficial aquifer. The BTEX and MTBE results are summarized in Table 2.2 and shown on Figure 2.2. The results of the natural attenuation sampling are presented in Section 5. The extent of the plume associated with total BTEX in the groundwater is shown on Figure 2.3. This figure also shows the plume originating from the vicinity of Building 1504. Laboratory data sheets for this sampling event are presented in Appendix A.

The analysis for BTEX and MTBE was performed by EPA Method 8021B. BTEX constituents were detected in wells MW8-3, MW8-4, MW8-5, MWA-7, MWA-9, MWA-11, and MWA-13. The total BTEX concentrations ranged from non-detect to 3,694 µg/L in MW8-3. The Mississippi Department of Environmental Quality (MDEQ) cleanup level for total BTEX is 18,000 µg/L. MTBE was detected only in well MWA-11 at a concentration of 3.2 µg/L. *

Comparison of the current analytical results with data from November, 1992 and February, 1998 indicates plume attenuation near and downgradient of the source area is occurring. Total BTEX concentrations decreased approximately 91% in MWA-11 near the source area. Downgradient of the source area total BTEX levels decreased by approximately 84% in MW8-3 and 59% in MW8-4. Both of these wells showed a net *

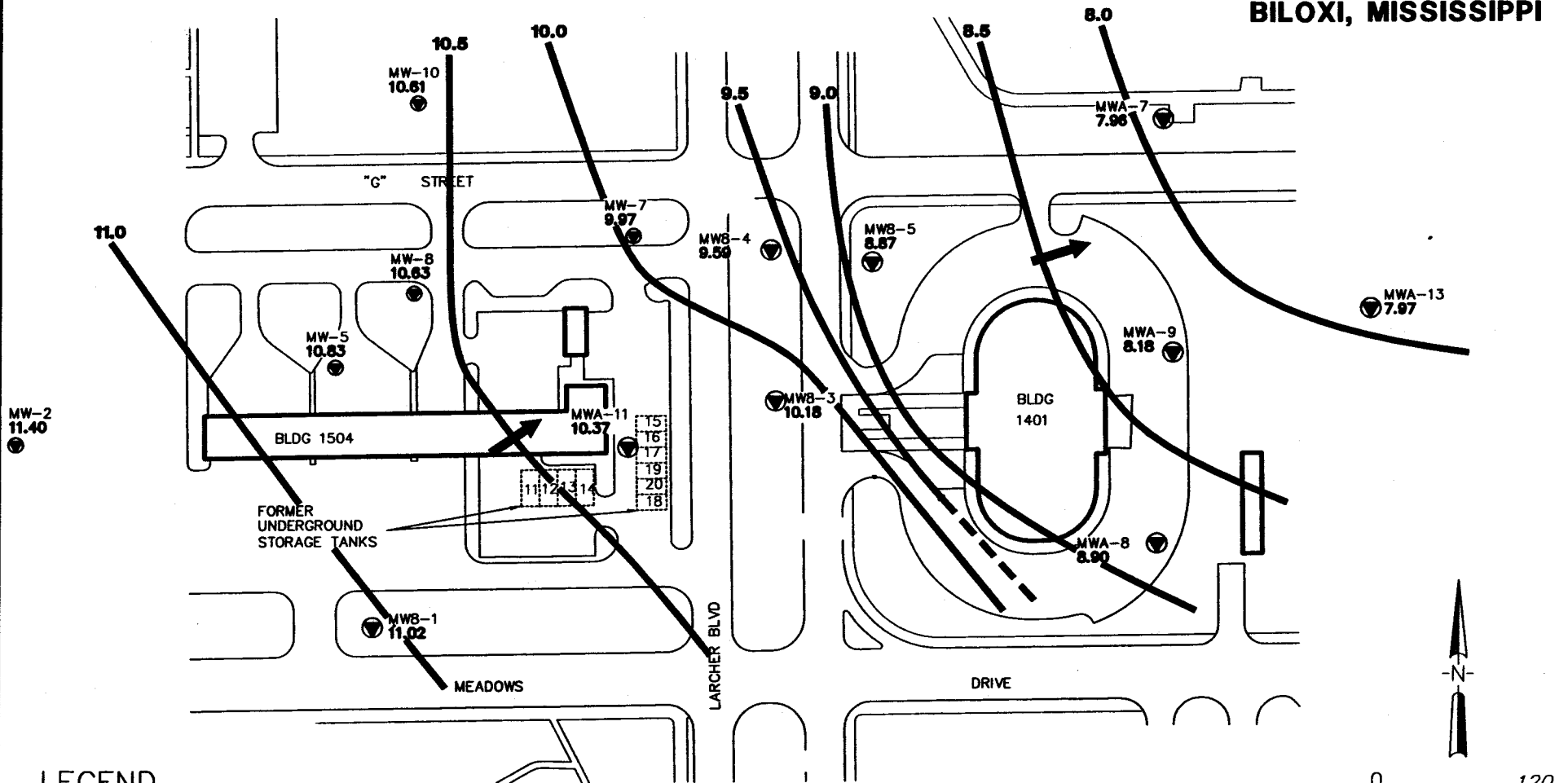
BTEX increase in February, 1998 followed by a significant reduction in June, 1999. A similar trend is anticipated to occur in monitoring wells further downgradient as the plume attenuates. Further discussion of the plume attenuation and assimilative capacity estimates are contained in Section 5 of this document.

2.3 FIELD DETERMINED PARAMETERS

Parameters measured in the field during well purging activities included temperature, conductivity, pH, and dissolved oxygen. These parameters are summarized in Table 2.3. The values in this table represent the last reading recorded after stabilization of purging parameters. Groundwater sampling records/forms are presented in Appendix B.

JANUARY 2000

**FIGURE 2.1
POTENTIOMETRIC MAP
FACILITY 1504 & AOC-A
KEESLER AFB
BILOXI, MISSISSIPPI**



LEGEND

- MONITORING WELL
- 10 — GROUNDWATER ELEVATION CONTOUR, FEET MSL
- 11.63 GROUNDWATER ELEVATION FEET MSL - JUNE 23, 1999
- GROUNDWATER FLOW DIRECTION

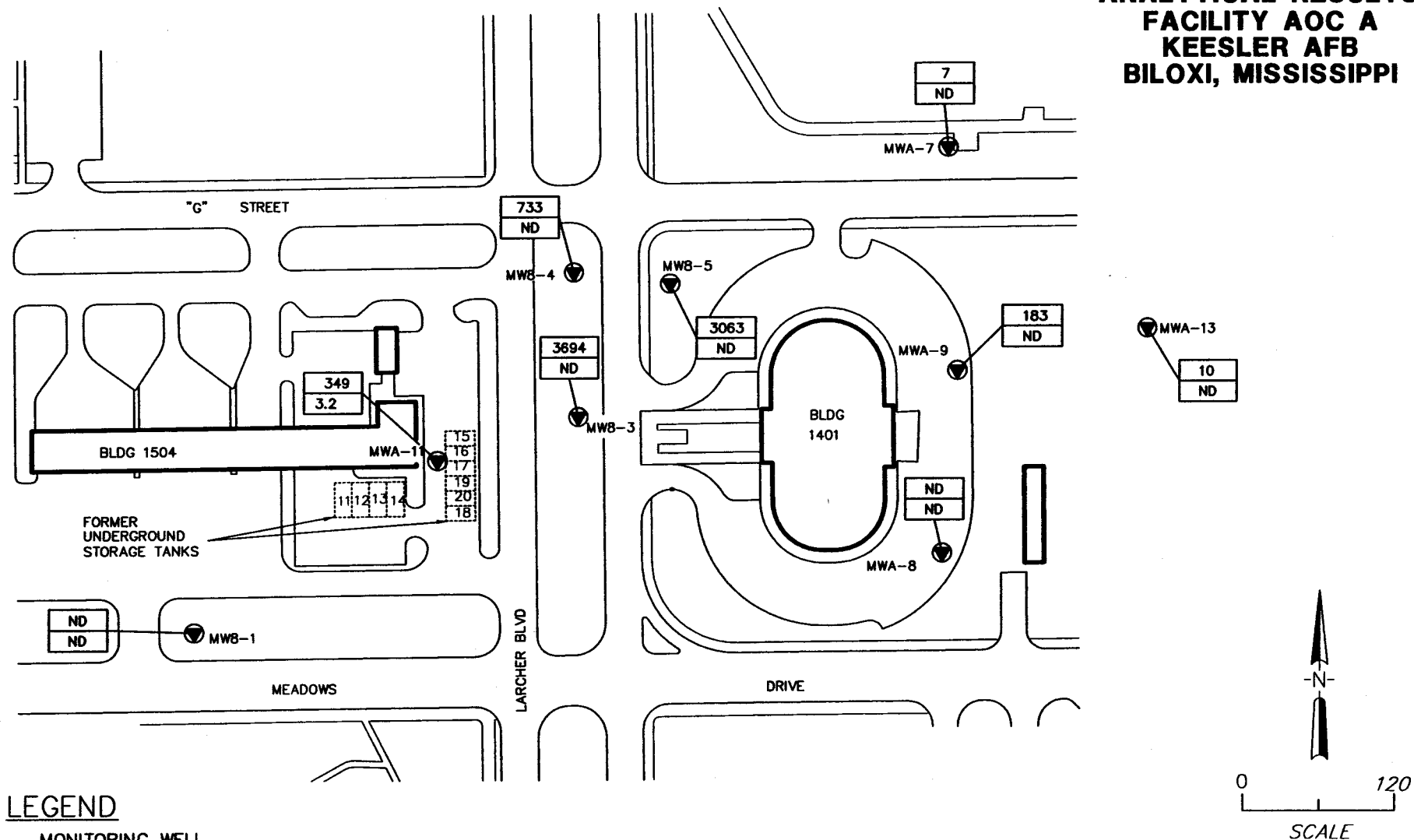
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FIGURE 2.2
GROUNDWATER
ANALYTICAL RESULTS
FACILITY AOC A
KEESLER AFB
BILOXI, MISSISSIPPI



**FIGURE 2.3
DISTRIBUTION OF
TOTAL BTEX
FACILITY 1504 & AOC A
KEESLER AFB
BILOXI, MISSISSIPPI**

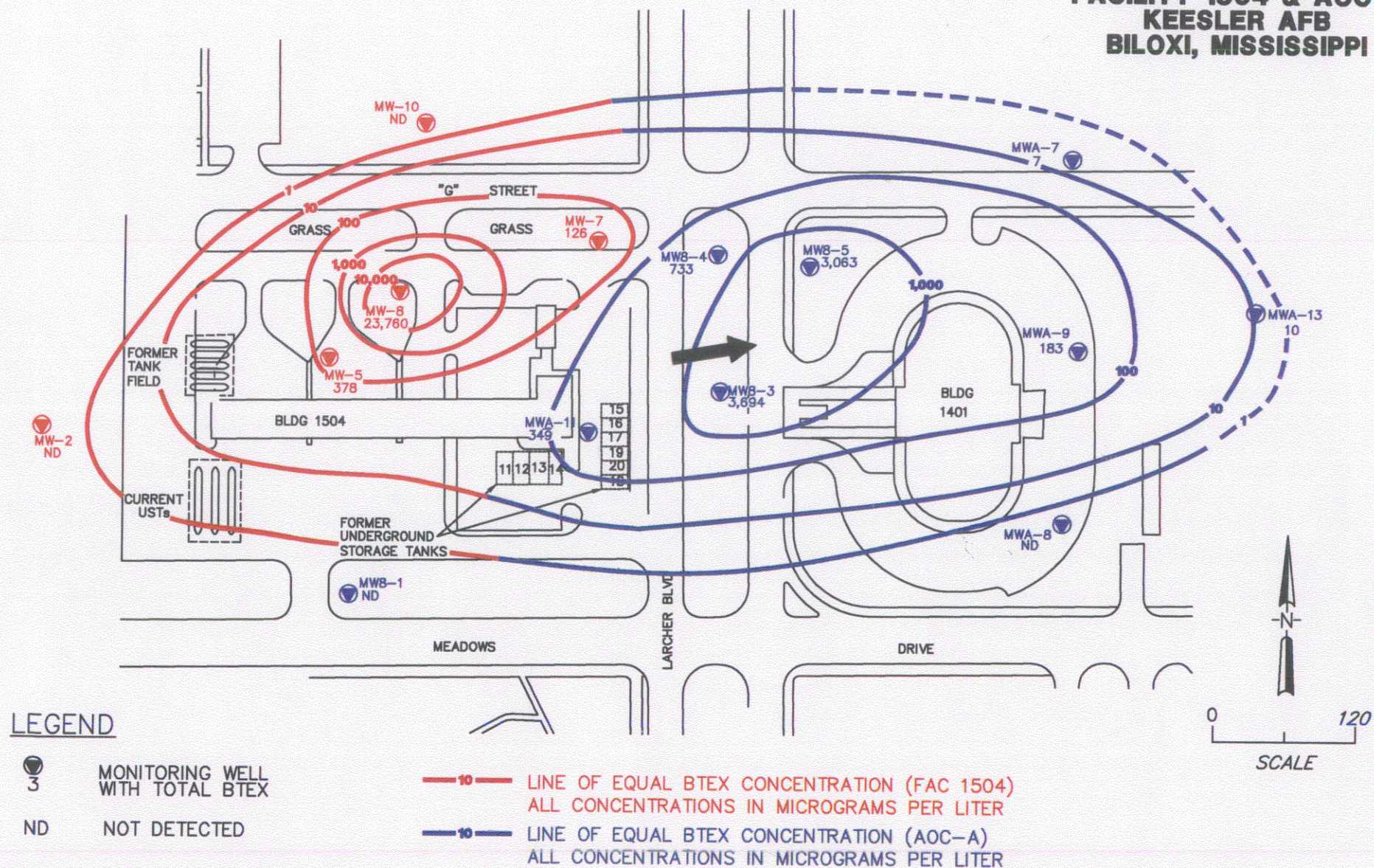


Table 2.1
Summary of Monitoring Well Gauging Data
AOC A
June 23, 1999
Keesler AFB, MS

Well Identification	Top of Casing Elevation (feet)	Depth to Water (feet btoc)	Water Table Elevation (feet)
Facility 1504			
MW-1	18.13	6.86	11.27
MW-2	19.46	8.06	11.40
MW-3	19.29	8.09	11.20
MW-4	18.70	7.99	10.71
MW-5	19.87	9.04	10.83
MW-7	18.73	8.76	9.97
MW-8	19.57	8.94	10.63
MW-9	19.54	8.71	10.83
MW-10	18.06	7.45	10.61
AOC-A			
MW8-1	18.43	7.41	11.02
MW8-3	18.96	8.78	10.18
MW8-4	18.40	8.81	9.59
MW8-5	18.99	10.12	8.87
MWA-7	18.25	10.29	7.96
MWA-8	18.55	9.65	8.90
MWA-9	18.61	10.43	8.18
MWA-11	19.26	8.89	10.37
MWA-13	18.34	10.37	7.97

Notes:

ft bgs = feet below ground surface
ft btoc = feet below top of casing

Table 2.2
Groundwater Analytical Results
Area of Concern A
Keesler Air Force Base
Biloxi, Mississippi

Location:	MDEQ	MW8-1	MW8-3	MW8-4	MW8-5	MWA-7	MWA-8	MWA-9	MWA-11	MWD-11*	MWA-13
Sample Date:	Cleanup Level	6/23/1999	6/24/1999	6/24/1999	6/23/1999	6/23/1999	6/22/1999	6/22/1999	6/24/1999	6/24/1999	6/22/1999
SW8021B (ug/L)											
Benzene		< 1.0	520	489	766	< 1.0	< 1.0	1.7	158	144	< 1.0
Toluene		< 1.0	2130	27	77	4.2	< 1.0	1.1	98.4	79.5	5.9
Ethylbenzene		< 1.0	234	54	840	< 1.0	< 1.0	25.2	35.1	32.2	< 1.0
Xylenes		< 1.0	810	163	1380	2.6	< 1.0	155	57	51.5	4.5
MTBE		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.2	3	< 1.0
Total BTEX	18,000	< 4.0	3694	733	3063	7	< 4.0	183	349	307	10

Note:

Bolded results indicate detected compounds.

*MWD-11: Duplicate of MWA-11

ug/L = parts per billion

Table 2.3
Initial Groundwater Screening Summary
AOC A
Keesler AFB, MS

Monitoring Well ID	Purge Data				
	Temperature (°C)	pH	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Gallons Purged
MW8-1	25.2	5.63	254	0.01	2
MW8-3	25	6.38	498	0.03	2
MW8-4	24.4	6.26	313	0.03	2
MW8-5	24.7	5.58	147	0.02	4
MWA-7	22.9	5.91	263	0.18	3
MWA-8	26.9	4.77	118	0.08	2
MWA-9	26.4	5.76	175	0	2.5
MWA-11	27.8	6.18	285	0	6
MWA-13	24.1	5.69	164	0	4

Values represent last reading taken after equilibrium was reached

SECTION 3

SAMPLE COLLECTION PROCEDURES AND QUALITY ASSURANCE / QUALITY CONTROL

3.1 SAMPLE COLLECTION

Groundwater sampling was conducted at AOC A on June 22-24, 1999. To the extent possible, the monitoring wells were sampled in order of increasing groundwater contaminant concentrations to minimize cross contamination potential. All sample collection activities and field observations were recorded in the field logbook or on groundwater sampling forms. Copies of the sampling forms are included as Appendix B. General procedures for the handling and collection of groundwater samples during this round of sampling are described in the following sections.

3.1.1 Groundwater Sampling and Handling

Prior to purging, the static water levels and depth to bottom of the wells were measured to the nearest 0.01 foot from the top of the well casing (TOC) using a clean water level indicator. Prior to the collection of groundwater samples at each location, each well was purged using a peristaltic pump. The purging rate was less than one liter per minute. Field parameters including pH, conductivity, dissolved oxygen and temperature were measured during the purging process to ensure that representative samples of the aquifer water were collected. Purging activities continued until these parameters stabilized (less than ± 0.2 standard pH units or a 10-percent change for the other parameters), or until a minimum of three well casing volumes of groundwater had been removed. The meter used to measure the field parameters (Horiba U-10) was calibrated each day prior to use. Table 2.3 summarizes the final field parameter measurements collected during the purging process. The purge water was containerized and later taken to an on-site oil/water separator for disposal.

Groundwater samples were collected using a peristaltic pump with new polyethylene tubing following stabilization of field parameters. The samples were placed in appropriate pre-labeled containers and securely sealed. The bottle labels indicated the sample number and source, sampler's initials and date of sample collection. Sample collection times and all other pertinent information was entered on groundwater sampling forms (Appendix B) or in the bound field logbook. Chain of custody forms accompanied the samples throughout all phases of sample shipment and handling. The samples were placed on ice in a cooler to maintain a temperature of 4 degrees centigrade, and then shipped to

Specialized Assays Laboratory in Nashville, TN for analysis. The groundwater samples and quality control (QC) samples were analyzed as specified in Section 2.2. Laboratory blanks accompanied each set of sample analyses. The results of these blank analyses and other QC sample results are discussed below.

3.2 QUALITY ASSURANCE/QUALITY CONTROL

Quality Assurance/Quality Control (QA/QC) includes the assessment of precision, accuracy, representativeness, comparability and completeness. QA/QC is evaluated by the review of the field and laboratory methodologies, the collection and analysis of field QC samples (trip blanks and coded field duplicates), as well as the internal laboratory QC analyses (surrogate spikes, method blanks, laboratory control sample/laboratory control sample duplicates). The results of the QA/QC review are presented in Appendix C.

SECTION 4

POTENTIAL RECEPTORS AND MIGRATION PATHWAYS

4.1 POTENTIAL EXPOSURE PATHWAYS

The potential routes of migration for the petroleum hydrocarbons at AOC A are leaching from soil to groundwater, volatilization from soils and groundwater with subsequent vapor-phase movement, and transport with groundwater flow. Human exposure pathways can exist for inhalation, ingestion and dermal contact of site contaminants in various site media that include groundwater, subsurface soils, soil vapor and surface soils. This section discusses the fate, transport, and potential exposure pathways of the contaminants of concern at AOC A.

In order to determine which populations may be exposed to hydrocarbons at AOC A, it is necessary to evaluate current and future use of the property. By identifying current and future land use, potentially exposed populations can be identified and the exposure pathways can be evaluated. Currently, Keesler AFB is used as an Air Education and Training Command Base. In the future, Keesler AFB will likely continue to be used for similar or other military purposes.

4.1.1 Surface Water Receptor Pathways

Discharge to local surface water does not appear to be a current risk factor associated with hydrocarbons in groundwater beneath AOC A. The closest potential aquifer discharge point is the Back Bay of Biloxi Sound located approximately 2,000 feet northeast of the site.

4.1.2 Soil Hydrocarbon Receptor Pathways

Residual hydrocarbons exist in shallow soils at AOC A. Inhalation, ingestion, and dermal exposure to soils impacted by hydrocarbons are possible exposure pathways associated with this site. These soils are sufficiently deep to minimize the potential for incidental contact or soil migration away from the site. The potential exposure risk for soils increases during excavation or other intrusive activities.

The entire base is fenced with guarded gates to prevent unauthorized access to this site. The most likely receptors for exposure to the contaminants are future site workers involved with excavation activities. However, by advising site workers of hazard potentials and wearing appropriate protective safety equipment, exposure potential can be

minimized or eliminated. The risk potential for hydrocarbon inhalation is insignificant at the site in its current undisturbed condition. However, the risk for inhalation of hydrocarbons would increase during activities that disturb and expose subsurface soils. Through the use of appropriate safety equipment, complete pathways for exposure to the contaminants are eliminated or reduced to acceptable levels for industrial workers during intrusive activities.

4.1.3 Groundwater Receptor Pathways

Groundwater is the primary mechanism for potential off-site hydrocarbon migration. However, human ingestion of hydrocarbons via groundwater consumption is a very low risk associated with this site. No water supply wells exist in the surficial aquifer on Keesler AFB. Therefore, a complete exposure pathway does not exist. Groundwater for consumptive purposes is obtained from the Graham Ferry Formation which is part of the Miocene aquifer system. The surficial aquifer system is separated from the Graham Ferry Formation by less permeable stratigraphic units contained in the upper part of the formation. Therefore a pathway of exposure by consumption or dermal contact is not present.

Even though a complete exposure pathway does not exist at SWMU 66, MDEQ regulates the surficial aquifer as a drinking water source. The proposed corrective action at SWMU 66 includes land use controls which would prevent future development of the site and would also prevent the usage of site groundwater by potential human receptors.

4.2 WATER-SUPPLY WELL SURVEY

Keesler AFB obtains water from a system of 11 potable supply wells all of which pump from the 600-ft sands. These wells range in depth from 611 to 684 feet. Two of the wells are located west of the main base, near the V.A. Hospital. The remaining wells are located south and east of the runway. Newcome (1968) reported a daily pumping rate at Keesler AFB of 3.6 million gallons per day (gpd). Aquifer tests were performed on six of the Keesler AFB wells in 1964. In short, the aquifer thickness of the 600-ft sands ranged from 60 to 100 ft with an average thickness of 84 ft. Transmissivity in these six wells ranged from 60,000 to 100,000 gpd/ft and hydraulic conductivity ranged from 670 to 1000 gpd/ft². Storage coefficients were reported for base wells number 1 and 5 as 0.0003 and 0.0004 (Colson and Boswell 1985). A summary of water-supply wells at Keesler AFB is given in Table 4.1. Figure 4.1 illustrates the relative locations of these wells to AOC A. The nearest well to AOC A is Well 4 located approximately 400 feet southeast of the study area.

FIGURE 4.1
GROUNDWATER WELLS
RELATIVE TO AOC A
KEESLER AIR FORCE BASE
BILOXI, MISSISSIPPI

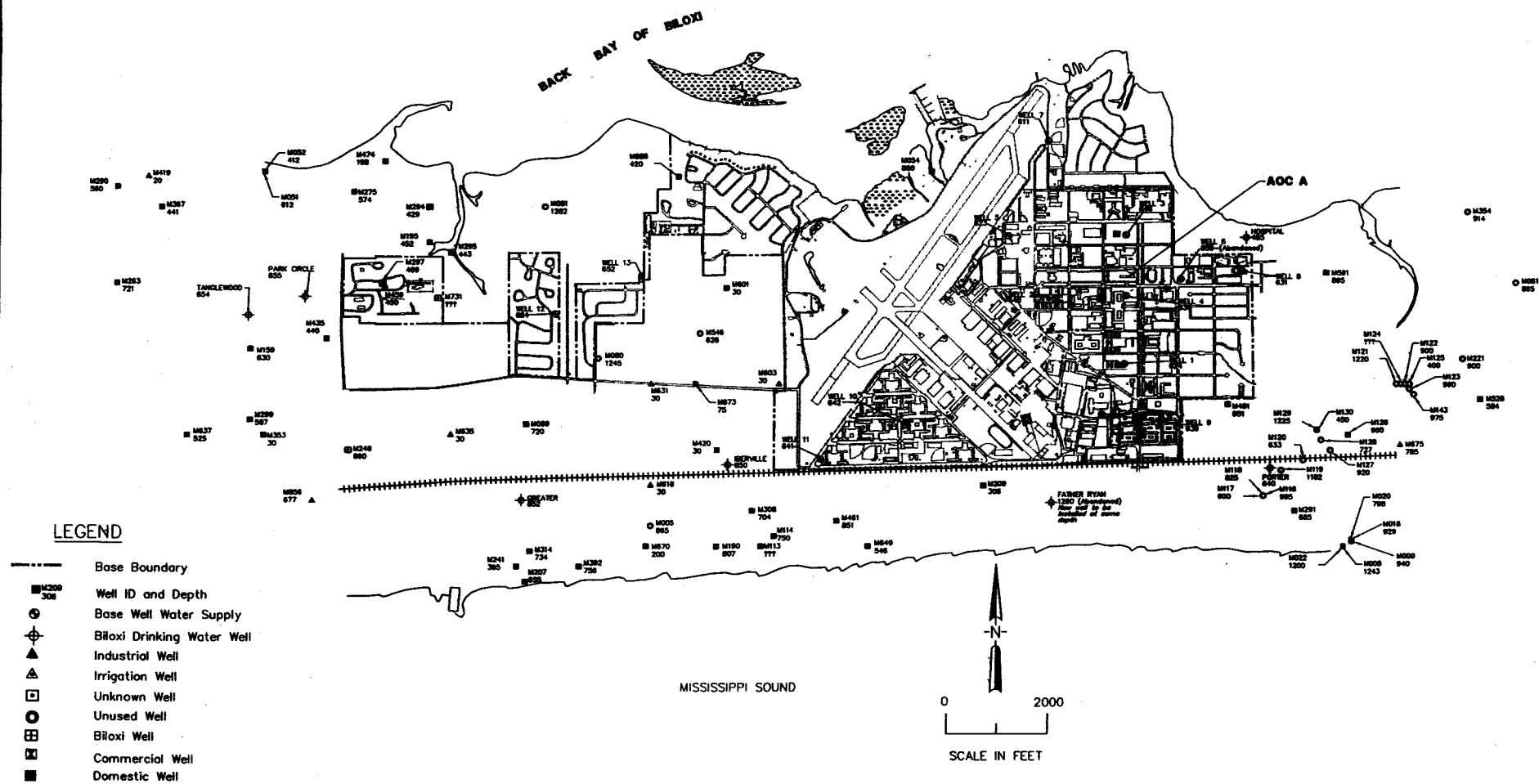


Table 4.1
Keesler AFB Water Supply Wells

Well Number	Building	USGS Number	Well Depth (ft)	Static Water Level (ft below land surface datum)	Measurement Date	Screen Diameter (inches)	Screen Length (ft)	Primary Aquifer (USGS Classification)	Transmissivity GPD/ft	Hydraulic Conductivity GPD/ft ²	Storage Coefficient
1	3509	M64	624	71.0	1986	10	40	Graham Ferry, fm	100,000	1,000	0.0003
2	1921	M67	640	76.0	1986	10	40	Graham Ferry, fm	--	--	--
3	0621	M66	646	76.0	1986	10	40	Graham Ferry, fm	--	--	--
4	2121	M65	636	73.0	1986	10	40	Graham Ferry, fm	--	--	--
5	0916	M68	623	70.0	1986	10	40	Graham Ferry, fm	60,000	1,000	0.0004
6(a)	5705	M63	650	2.0	1942	10	50	Graham Ferry, fm	--	--	--
7	0242	M75	611	75.0	1986	12	40	Graham Ferry, fm	62,000	960	--
8	6005	M76	631	74.0	1986	12	40	Graham Ferry, fm	67,000	670	--
19	3967	M77	639	83.0	1986	12	40	Graham Ferry, fm	--	--	--
10	7301	M78	642	74.0	1986	12	40	Graham Ferry, fm	73,000	730	--
11	7501	M79	641	81.0	1986	12	40	Graham Ferry, fm	80,000	1,000	--
12	9161	M82	684	48.0	1978	10	60	Graham Ferry, fm	--	--	--
13	7721	M650	652	50	1986	10	85	Graham Ferry, fm	--	--	--
(b)	6634	M681	60	0.5(c)	1984	4	--	--	--	--	--

(a) Abandoned

(b) This well is used to maintain the water level in the golf course pond; it is not used as a drinking water source.

(c) Water level is 0.5 ft above local land surface datum.

Sources: USGS file data

Brown et al., 1944; Newcome, 1968; USGS file data, 1993; Colson-Boswell, 1985

ES, 1984; ESE, 1991

SECTION 5

CONTAMINANT ATTENUATION ASSESSMENT

5.1 INTRODUCTION

Biodegradation of dissolved fuel constituents is assessed in this section and Appendix D to support selection of an appropriate remedial alternative for Facility 1504 and AOC-A. Facility 1504 and AOC-A were studied as one site due to the presence of commingled hydrocarbon plumes. As used throughout this report, the term "remediation by natural attenuation" (RNA) refers to a subsurface contaminant management strategy that relies on natural physical, chemical, and biological mechanisms to control exposure of potential receptors to concentrations of contaminants in soil and groundwater that exceed regulatory levels. These mechanisms include the processes of hydrodynamic dispersion, dilution, sorption, volatilization, and biodegradation, which facilitate RNA of a variety of anthropogenic chemicals.

This section summarizes the contaminant attenuation assessment for Facility 1504 and AOC-A. The full assessment for this site is presented in Appendix D.

5.2 EVIDENCE OF CONTAMINANT BIODEGRADATION OVER TIME

The first step in determining whether fuel hydrocarbon constituents are biodegrading in soils and groundwater at Facility 1504 and AOC-A was to compare contaminant concentrations at selected sampling locations over time. The purpose of this comparison was to assess the evidence of field-scale contaminant mass loss. Decreases in the magnitude of contaminant concentrations at a site over time that cannot be explained by physical processes (e.g., source removal, mass transport in groundwater) may be the first indication that contaminants are biodegrading at the site.

5.2.1 Hydrocarbon Concentration Trends in Soil

Biodegradation of soil hydrocarbons present in the vadose zone can proceed if the soil particles to which the contaminants are adsorbed are covered with a water film that supports microbial populations. The presence of abundant soil moisture in the vadose zone can be inferred from the shallow water table depth, the relatively warm ambient air temperature, and the presence of the asphalt/concrete cap over much of the site that would inhibit evaporation of subsurface moisture into the atmosphere. Comparison of soil data from April 1995 to September 1998 indicated the maximum BTEX

concentration decreased in the soil (Parsons, 1999 and Parsons ES, 1998b). No soil samples were collected in the 1999 sampling event.

5.2.2 Hydrocarbon Concentration Trends in Groundwater

Hydrocarbon concentrations were measured from five monitoring wells at Facility 1504 in 1995, 1998, and 1999 and from nine monitoring wells at AOC-A in 1992, 1998, and 1999; the data are summarized in Appendix D, Tables D.1 and D.2, respectively. Within Facility 1504, four of the five wells had total BTEX concentrations that decreased or were consistently below detection limits. BTEX concentrations in MW-5 and MW-8 slightly increased from 1998 to 1999, but were still lower than the 1995 concentrations. Total BTEX in MW-7 increased substantially from 2.5 µg/L in 1998 to 126 µg/L in 1999 and can be attributed to the mass transport of the plume in the groundwater.

Total BTEX concentrations decreased substantially or remained below detection limits in five of the nine wells. The maximum BTEX concentration in 1998 of 22,400 µg/L at MW8-3 decreased to 3,694 µg/L in 1999. BTEX concentrations at MW8-5 steadily increased from 272 µg/L in 1992 to 3,063 µg/L in 1999. Total BTEX in monitoring wells MWA-7 and MWA-13, which are on the down gradient edge of the plume, increased slightly from non-detect to 6.8 and 10.4 µg/L, respectively.

Decreasing dissolved hydrocarbon concentrations indicate that the mass of hydrocarbons input into the groundwater system in the source area (through leaching of residual hydrocarbons in soils) is decreasing, and that biodegradation of dissolved BTEX is occurring.

5.3 EVIDENCE OF CONTAMINANT BIODEGRADATION VIA MICROBIALY MEDIATED REDOX REACTIONS

Groundwater geochemical data can be used to show that fuel hydrocarbons are biodegrading in saturated soil and groundwater at Facility 1504 and AOC-A. Fuel hydrocarbon constituents are typically utilized as electron donors in biologically mediated redox reactions under a wide range of geochemical conditions. Therefore, analytical data on potential electron acceptors can be used as geochemical indicators of fuel hydrocarbon biodegradation (Wiedemeier *et al.*, 1995). Reductions in the concentrations of oxidized chemical species that are used by microorganisms to facilitate the oxidation of fuel hydrocarbon compounds within contaminated media are an indication that contaminants are biodegrading. Alternately, an increase in the metabolic byproducts resulting from the reduction of electron acceptors can be used as an indicator of contaminant biodegradation. The availability of potential electron acceptors to participate in contaminant biodegradation reactions can be used to estimate the total contaminant mass that can be biodegraded over time at this site. Coupled with calculated biodegradation rates, this information can be used to predict how much and how quickly fuel hydrocarbons can be

removed from saturated soils and groundwater at Facility 1504 and AOC-A as a result of natural processes only.

Throughout the following subsections, the distributions of geochemical parameters are examined by comparing background concentrations to fuel hydrocarbon plume core concentrations. Analytical data from upgradient well MW-2 is used for background concentrations. Analytical data from MW-8, MW8-3, MW8-4, and MW8-5 are used for fuel hydrocarbon plume core concentrations. Hydrocarbon concentrations are presented on Figure 2.2. The following shows qualitatively the expected geochemical parameter response to biodegradation of BTEX compounds, with \uparrow referring to relatively high concentrations and \downarrow referring to relatively low concentrations (Payne, *et al.* 1995):

BTEX \uparrow : $O_2 \downarrow$ $NO_3^- \downarrow$ $NH_3 \uparrow$ $Fe^{2+} \uparrow$ $SO_4^{4-} \downarrow$ $H_2S \uparrow$ $CH_4 \uparrow$

BTEX \downarrow : $O_2 \uparrow$ $NO_3^- \uparrow$ $NH_3 \downarrow$ $Fe^{2+} \downarrow$ $SO_4^{4-} \uparrow$ $H_2S \downarrow$ $CH_4 \downarrow$

5.3.1 Dissolved Oxygen (O_2)

The overall low magnitude of DO concentrations indicates that oxygen is not currently a significant electron acceptor during microbially mediated degradation of fuel hydrocarbons at Facility 1504 and AOC-A. However, a periodic contribution to dissolved oxygen from rainfall can be expected.

5.3.2 Ammonia (NH_3)

Ammonia concentrations detected in shallow groundwater varied across the site, with elevated ammonia concentrations occurring in the fuel hydrocarbon plume core area. Therefore, production of ammonia appears to be occurring due to increased microbial activity stimulated by the relative abundance of organic carbon (fuel hydrocarbons).

5.3.3 Ferrous Iron (Fe^{2+})

The occurrence of elevated ferrous iron concentrations within contaminated areas indicates that ferric iron is acting as an electron acceptor at these locations.

5.3.4 Sulfate (SO_4^{4-})

In general, there is a good correlation between areas of depleted sulfate concentrations and the plume core. The decrease of sulfate within the contaminated area indicates microbial populations are using sulfate to oxidize fuel hydrocarbons at the site.

5.3.5 Dissolved Methane (CH_4)

The presence of elevated methane levels in groundwater at Facility 1504 and AOC-A strongly indicates biodegradation is occurring via methanogenesis.

5.4 THEORETICAL ASSIMILATIVE CAPACITY ESTIMATES

On the basis of theoretical assimilative capacity calculations performed in Appendix D, one pore volume of saturated soil and groundwater at Facility 1504 and AOC-A has the capacity to oxidize an average BTEX concentration of approximately 13.03 mg/L (13,030 µg/L) (Appendix D, Table D.6). The maximum BTEX concentration at Facility 1504 and AOC-A in June 1999 was 23.76 mg/L (23,760 µg/L).

This estimate essentially represents an estimate of the fuel hydrocarbon reduction capability of one pore volume of groundwater at Facility 1504 and AOC-A. The estimate identifies how much contaminant mass can be theoretically oxidized as one pore volume travels through the plume core. In reality, one pore volume is expected to move through the contaminated aquifer material in the source area every 3.45 years based on the estimated groundwater velocity of 292 ft/yr and a source area length of approximately 1008 feet.

5.5 SUMMARY OF FINDINGS

The results of chemical fate assessment performed in this section are as follows:

1. Historical groundwater analytical data indicate that BTEX concentrations are decreasing over time;
2. Geochemical data strongly indicate that biodegradation of fuel hydrocarbons is occurring primarily through the processes of iron reduction, sulfate reduction, nitrogen fixation and methanogenesis; and
3. The expressed BTEX assimilative capacity of the aquifer (13.03 mg/L) is less than the maximum BTEX concentration detected in Facility 1504 and AOC-A groundwater (23.76 mg/L).

These results are discussed in detail in Appendix D.

SECTION 6 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are provided based on the current monitoring data, historical analytical results, and the natural attenuation assessment conducted.

6.1 CONCLUSIONS

- The groundwater flow direction at the site is generally toward the east.
- BTEX constituents were detected in seven of the nine wells sampled during this quarterly sampling event.
- None of the total BTEX concentrations exceeded the MDEQ cleanup level. MTBE was detected in MWA-11 only.
- Total BTEX concentrations have significantly decreased in MWA-11 (91%), MW8-3 (84%), and MW8-4 (59%) from historical levels, indicating plume attenuation is occurring.
- Low levels of DO indicate oxygen is not currently a significant electron acceptor for microbial degradation of fuel hydrocarbons.
- Ammonia production, ferric iron reduction, sulfate reduction, methanogenesis were determined to be active microbial processes at AOC A for the natural attenuation of residual fuel hydrocarbons.
- Assimilative capacity estimates indicate that one pore volume of saturated soil and groundwater has the capacity to oxidize an average BTEX concentration of 13.03 mg/L (13,030 µg/L).

6.2 RECOMMENDATIONS

Current groundwater data indicate the hydrocarbon plume at AOC A is attenuating. It is recommended that the current monitoring schedule approved by the USEPA and MDEQ be followed to monitor the reduction of the residual hydrocarbons in groundwater. This consists of quarterly sampling for BTEX and MTBE for three more quarters, followed by annual sampling for the next four years. Natural attenuation parameters will be evaluated on an annual basis for the remainder of the monitoring period.

SECTION 7 REFERENCES

- Battelle-Columbus, Inc. 1995, Final Report on Field Treatability Study for Keesler AFB, MS.
- BCM, Inc. 1996, Well Assessment Report, Long Term Monitoring Program, Keesler AFB, Biloxi, Mississippi.
- Colson, B.E. and E.H. Boswell, 1985. Water-Resources Overview of the Mississippi Gulf.
- Environmental Science and Engineering (ESE), 1991. Installation Restoration Program Final Site Characterization Report, Keesler AFB, Mississippi. Prepared for U.S. Air Force HQ ATC/DEEV, Randolph AFB, Texas and HSD/YAQ Brooks AFB, Texas. Gainesville, Florida.
- Kearney, A.T. Inc. and Pope – Reid Associates, Inc. 1987. RCRA Facility Assessment Report, Keesler AFB, Mississippi. Prepared for U.S. EPA Region IV, Atlanta, Georgia, September 1987.
- Newcome, R., D.E. Shattles, and C.P. Humphreys, 1968. Water for the Growing Needs of Harrison County, Mississippi, *U.S. Geological Survey Water-Supply paper No. 1856*.
- Parsons Engineering Science, Inc, 1999. Keesler Air Force Base U.S. Installation Restoration Program Final RCRA Facility Investigation Report. Prepared for U.S. Air Force. EPA I.D. No. MS2 570 024 164. Atlanta, Georgia.
- Wasatch Environmental Inc. (WEI). 1997, Draft Final Report, DDC In-Well Aeration Technology Demonstration, Keesler AFB, Biloxi, Mississippi.

APPENDIX A
LABORATORY DATA



SPECIALIZED ASSAYS, INC.

2960 Foster Creighton Dr.
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ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95486
Sample ID: ADLA MW 8-1
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/23/99
Time Collected: 14:50
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Ruan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	ND	ug/l	1.0	1.0	1	7/ 4/99	15:47	D. Raney	8021B	7193
Toluene	ND	ug/l	1.0	1.0	1	7/ 4/99	15:47	D. Raney	8021B	7193
Ethylbenzene	ND	ug/l	1.0	1.0	1	7/ 4/99	15:47	D. Raney	8021B	7193
Xylenes, total	ND	ug/l	1.0	1.0	1	7/ 4/99	15:47	D. Raney	8021B	7193
Methyl-t-butylether	ND	ug/l	1.0	1.0	1	7/ 4/99	15:47	D. Raney	8021B	7193
MISCELLANEOUS GC PARAMETERS										
Methane	75.0	ug/l	26.0	26.0	1	7/ 6/99	17:37	H. Rogers	RSK175M	4622

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
BTX/GRD Surr., a,a,a-trifluorotoluene	85.	50. - 150.

Report Approved By:

Gail A. Lage

Report Date: 7/16/99

Theodore J. Duello, Ph.D., Lab Director
Michael H. Dunn, M.S., Technical Director
Johnny A. Mitchell, Dir. Technical Services
Eric Smith, Assistant Technical Director
Gail A. Lage, Technical Services

Laboratory Certification Number: 387



SPECIALIZED ASSAYS, INC.

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ANALYTICAL REPORT

PARSONS ENG./KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95494
Sample ID: ADLA MW 8-3
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/24/99
Time Collected: 9:50
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	520.	ug/l	20.0	1.0	20	7/ 4/99	21:40	D. Raney	8021B	7193
Toluene	2130	ug/l	20.0	1.0	20	7/ 4/99	21:40	D. Raney	8021B	7193
Ethylbenzene	234.	ug/l	20.0	1.0	20	7/ 4/99	21:40	D. Raney	8021B	7193
Xylenes, total	810.	ug/l	20.0	1.0	20	7/ 4/99	21:40	D. Raney	8021B	7193
Methyl-t-butylether	ND	ug/l	20.0	1.0	20	7/ 4/99	21:40	D. Raney	8021B	7193

MISCELLANEOUS GC PARAMETERS

Methane	656.	ug/l	26.0	26.0	1	7/ 6/99	18:56	N. Rogers	RSK175M	4622
---------	------	------	------	------	---	---------	-------	-----------	---------	------

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
KTEX/GRD Surr., a,a,a-trifluorotoluene	84.	50. - 150.

Report Approved By:

Gail A. Lage

Report Date: 7/16/99

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ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95513
Sample ID: ADLA MW 8-4
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/24/99
Time Collected: 10:15
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	489.	ug/l	10.0	1.0	10	7/ 4/99	21:22	S. Stuart	8021B	7198
Toluene	27.0	ug/l	10.0	1.0	10	7/ 4/99	21:22	S. Stuart	8021B	7198
Ethylbenzene	54.0	ug/l	10.0	1.0	10	7/ 4/99	21:22	S. Stuart	8021B	7198
Xylenes, total	163.	ug/l	10.0	1.0	10	7/ 4/99	21:22	S. Stuart	8021B	7198
Methyl-t-butylether	ND	ug/l	10.0	1.0	10	7/ 4/99	21:22	S. Stuart	8021B	7198
MISCELLANEOUS GC PARAMETERS										
Methane	4490	ug/l	26.0	26.0	1	7/ 7/99	11:51	H. Rogers	RSK175M	4625

ND = Not detected at the report limit.

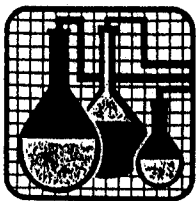
Surrogate	% Recovery	Target Range
BTEX/GRU Surr., a,a,a-trifluorotoluene	94.	50. - 150.

Report Approved By: Gail A. Lage

Report Date: 7/16/99

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ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95503
Sample ID: ADLA MW 8-5
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/23/99
Time Collected: 14:20
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	766.	ug/l	10.0	1.0	10	7/ 3/99	23:52	S. Stuart	8021B	7198
Toluene	77.0	ug/l	10.0	1.0	10	7/ 3/99	23:52	S. Stuart	8021B	7198
Ethylbenzene	840.	ug/l	10.0	1.0	10	7/ 3/99	23:52	S. Stuart	8021B	7198
Xylenes, total	1380	ug/l	10.0	1.0	10	7/ 3/99	23:52	S. Stuart	8021B	7198
Methyl-t-butylether	ND	ug/l	10.0	1.0	10	7/ 3/99	23:52	S. Stuart	8021B	7198
MISCELLANEOUS GC PARAMETERS										
Methane	3860	ug/l	26.0	26.0	1	7/ 6/99	19:45	M. Rogers	RSK175M	4625

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
BTEX/GRO Surr., a,a,a-trifluorotoluene	95.	50. - 150.

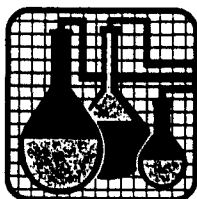
Report Approved By:

Gail A. Lage

Report Date: 7/16/99

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ANALYTICAL REPORT

PARSONS ENG./KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A93509
Sample ID: ADLA MWA-7
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/22/99
Time Collected: 11:15
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	ND	ug/l	1.0	1.0	1	7/ 4/99	18:48	S. Stuart	8021B	7198
Toluene	4.2	ug/l	1.0	1.0	1	7/ 4/99	18:48	S. Stuart	8021B	7198
Ethylbenzene	ND	ug/l	1.0	1.0	1	7/ 4/99	18:48	S. Stuart	8021B	7198
Xylenes, total	2.6	ug/l	1.0	1.0	1	7/ 4/99	18:48	S. Stuart	8021B	7198
Methyl-t-butylether	ND	ug/l	1.0	1.0	1	7/ 4/99	18:48	S. Stuart	8021B	7198
MISCELLANEOUS GC PARAMETERS										
Methane	40.0	ug/l	26.0	26.0	1	7/ 7/99	11:38	H. Rogers	RSK175M	4625

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
RTEX/GRD Surr., a,a,a-trifluorotoluene	102.	50. - 150.

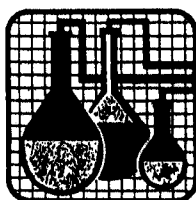
Report Approved By:

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Report Date: 7/16/99

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ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95510
Sample ID: ADLA MWA-8
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/22/99
Time Collected: 12:50
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	ND	ug/l	1.0	1.0	1	7/ 4/99	19:14	S. Stuart	8021B	7198
Toluene	ND	ug/l	1.0	1.0	1	7/ 4/99	19:14	S. Stuart	8021B	7198
Ethylbenzene	ND	ug/l	1.0	1.0	1	7/ 4/99	19:14	S. Stuart	8021B	7198
Xylenes, total	ND	ug/l	1.0	1.0	1	7/ 4/99	19:14	S. Stuart	8021B	7198
Methyl-t-butylether	ND	ug/l	1.0	1.0	1	7/ 4/99	19:14	S. Stuart	8021B	7198
MISCELLANEOUS GC PARAMETERS										
Methane	121.	ug/l	26.0	26.0	1	7/ 7/99	11:43	M. Rogers	RSK175M	4625

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
BTEX/GRO Surr., a,a,a-trifluorotoluene	102.	50. - 150.

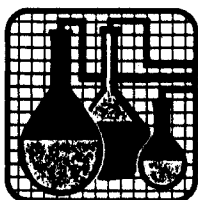
Report Approved By:

Gail A. Lage

Report Date: 7/16/99

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ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95511
Sample ID: ADLA MWA-9
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/22/99
Time Collected: 13:30
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	1.7	ug/l	1.0	1.0	1	7/ 4/99	20:31	S. Stuart	8021B	7198
Toluene	1.1	ug/l	1.0	1.0	1	7/ 4/99	20:31	S. Stuart	8021B	7198
Ethylbenzene	25.2	ug/l	1.0	1.0	1	7/ 4/99	20:31	S. Stuart	8021B	7198
Xylenes, total	155.	ug/l	1.0	1.0	1	7/ 4/99	20:31	S. Stuart	8021B	7198
Methyl-t-butylether	ND	ug/l	1.0	1.0	1	7/ 4/99	20:31	S. Stuart	8021B	7198
MISCELLANEOUS GC PARAMETERS										
Methane	596.	ug/l	26.0	26.0	1	7/ 7/99	11:46	H. Rogers	RSK175M	4625

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
BTEX/GND Surr., a,a,a-trifluorotoluene	100.	50. - 150.

Report Approved By:

Gail A. Lage

Report Date: 7/16/99

Theodore J. Duello, Ph.D., Lab Director
Michael H. Dunn, M.S., Technical Director
Johnny A. Mitchell, Dir. Technical Services
Eric Smith, Assistant Technical Director
Gail A. Lage, Technical Services

Laboratory Certification Number: 387



SPECIALIZED ASSAYS, INC.

2960 Foster Creighton Dr.
P.O. Box 40566
Nashville, TN 37204-0566
Phone 1-615-726-0177

ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95492
Sample ID: AOL A MWA-11
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/24/99
Time Collected: 8:40
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	158.	ug/l	1.0	1.0	1	7/ 4/99	18:44	D. Raney	8021B	7193
Toluene	98.4 J	ug/l	1.0	1.0	1	7/ 4/99	18:44	D. Raney	8021B	7193
Ethylbenzene	35.1	ug/l	1.0	1.0	1	7/ 4/99	18:44	D. Raney	8021B	7193
Xylenes, total	57.0	ug/l	1.0	1.0	1	7/ 4/99	18:44	D. Raney	8021B	7193
Methyl-t-butylether	3.2	ug/l	1.0	1.0	1	7/ 4/99	18:44	D. Raney	8021B	7193

MISCELLANEOUS GC PARAMETERS

Methane	258. J	ug/l	26.0	26.0	1	7/ 6/99	18:48	M. Rogers	RSK175M	4622
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ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
KTEX/GRD Surr., a,a,a-trifluorotoluene	100.	50. - 150.

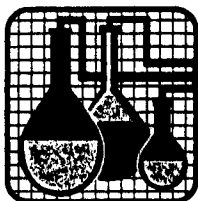
Report Approved By:

Gail A. Lage

Report Date: 7/16/99

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ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS 8249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95493
Sample ID: AOLA MWD-11
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/24/99
Time Collected: 9:30
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	144.	ug/l	1.0	1.0	1	7/ 4/99	19:14	D. Ramey	8021R	7193
Toluene	79.5 J	ug/l	1.0	1.0	1	7/ 4/99	19:14	D. Ramey	8021B	7193
Ethylbenzene	32.2	ug/l	1.0	1.0	1	7/ 4/99	19:14	D. Ramey	8021B	7193
Xylenes, total	31.5	ug/l	1.0	1.0	1	7/ 4/99	19:14	D. Ramey	8021R	7193
Methyl-t-butylether	3.0	ug/l	1.0	1.0	1	7/ 4/99	19:14	D. Ramey	8021R	7193
MISCELLANEOUS GC PARAMETERS										
Methane	173. J	ug/l	26.0	26.0	1	7/ 6/99	18:51	H. Rogers	RSK175N	4622

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
BTX/GRD Surr., a,a,a-trifluorotoluene	97.	50. - 150.

Report Approved By:

Gail A. Lage

Report Date: 7/16/99

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Phone 1-615-726-0177

ANALYTICAL REPORT

PARSONS ENG. /KEESLER AFB, MS B249
ROSS SURRENCY
5390 TRIANGLE PARKWAY STE 100
NORCROSS, GA 30092

Lab Number: 99-A95508
Sample ID: AOLA MWA-13
Sample Type: Water
Site ID:

Project: 735628.03
Project Name: KEESLER A. F. B.
Sampler: BURKINGSTOCK

Date Collected: 6/22/99
Time Collected: 10:45
Date Received: 6/26/99
Time Received: 9:00

Analyte	Result	Units	Report Limit	Quan Limit	Dil Factor	Date	Time	Analyst	Method	Batch
ORGANIC PARAMETERS										
Benzene	ND	ug/l	1.0	1.0	1	7/ 4/99	1:59	S. Stuart	8021B	7198
Toluene	5.9	ug/l	1.0	1.0	1	7/ 4/99	1:59	S. Stuart	8021B	7198
Ethylbenzene	ND	ug/l	1.0	1.0	1	7/ 4/99	1:59	S. Stuart	8021B	7198
Xylenes, total	4.5	ug/l	1.0	1.0	1	7/ 4/99	1:59	S. Stuart	8021B	7198
Methyl-t-butylether	ND	ug/l	1.0	1.0	1	7/ 4/99	1:59	S. Stuart	8021B	7198
MISCELLANEOUS GC PARAMETERS										
Methane	35.0	ug/l	26.0	26.0	1	7/ 7/99	11:30	M. Rogers	RSK175M	4625

ND = Not detected at the report limit.

Surrogate	% Recovery	Target Range
BTX/GRD Surr., a,a,a-trifluorotoluene	101.	50. - 150.

Report Approved By:

Gail A. Lage

Report Date: 7/16/99

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APPENDIX B
GROUNDWATER SAMPLING FORMS

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina AOC-A, SWMU 66, SWMU 64
Sampling Dates 6/23/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOC-A-MWB-1
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: 6/23, 1999 1450 a.m./p.m.

SAMPLE COLLECTED BY: BKB/BL of Parsons ES

WEATHER: Partly Cloudy

DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☐ LOCKED:

☒ UNLOCKED

WELL NUMBER (IS) IS NOT) APPARENT

STEEL CASING CONDITION IS: good

INNER PVC CASING CONDITION IS: good

WATER DEPTH MEASUREMENT DATUM (IS IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe):

2 ☐ PRODUCT DEPTH none FT. BELOW DATUM

WATER DEPTH DTW: 7.41' TD: 16.0' FT. BELOW DATUM

4 ☐ WELL EVACUATION:

Method: Peristaltic Pump

Volume Removed:

Observations: Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: Sulfur (slight)

Other comments: grey tint

5 ☐ SAMPLE EXTRACTION METHOD:

☐ Bailer made of:

☒ Pump, type: Peristaltic

☐ Other, describe:

6 ☐ ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1437	1441	1447				Measured With
Temp (°C)	25.3	25.3	25.2				
pH	5.52	5.58	5.63				
Cond (µS/cm)	239	247	254				
Do (mg/L)	0.36	0.07	0.01				
Redox (mv)	-126.8	-128.1	-110.0				
gallons purged	Initial	1 gal	2 gal				

Additional Comments:

7 ☐ SAMPLE CONTAINERS (material, number, size): 4-40ml VOAs (BTEX, MTBE, Methane)

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina AOA-A, SWMU 66, SWMU 64
Sampling Dates 6/24/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOA MW 8-3
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 6/24/99, 1999 0950 a.m./p.m.
SAMPLE COLLECTED BY: BKB/BL of Parsons ES
WEATHER: mostly sunny
DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☐ LOCKED: ☒ UNLOCKED
WELL NUMBER 15 IS NOT APPARENT
STEEL CASING CONDITION IS: good
INNER PVC CASING CONDITION IS: good
WATER DEPTH MEASUREMENT DATUM (IS IS NOT) APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe):

2 [] PRODUCT DEPTH none FT. BELOW DATUM
WATER DEPTH 8.8' 1621 FT. BELOW DATUM

4 [] WELL EVACUATION:
Method: Peristaltic Pump
Volume Removed:
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: Sulfur/hydrocarbon
Other comments: slight grey tint, clean

5 [] SAMPLE EXTRACTION METHOD:

☐ Bailer made of:
☒ Pump, type: peristaltic
☐ Other, describe:

6 [] ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	0935	0941	0946				Measured With
Temp (°C)	24.8	24.9	25.0				
pH	6.38	6.39	6.38				
Cond (µS/cm)	565	521	498				
Do (mg/L)	0.78	0.07	0.03				
Redox (mv)	-122.9	-145.2	-141.7				
gallons purged	Initial	1 gal	2 gal				

Additional Comments:

7 [] SAMPLE CONTAINERS (material, number, size): 4-40ml VOAS (BTEX, MTBE, Methane)

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina, AOC-A SWMU 66, SWMU 64
Sampling Dates 6/24/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOCA-MW⁸-4

(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: 6/24/, 1999 1015 a.m./p.m.

SAMPLE COLLECTED BY: BKB/BL of Parsons ES

WEATHER: Sunny

DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☐ LOCKED:

☒ UNLOCKED

WELL NUMBER (IS ~~IS NOT~~) APPARENT

STEEL CASING CONDITION IS: good

INNER PVC CASING CONDITION IS: good

WATER DEPTH MEASUREMENT DATUM (IS ~~IS NOT~~) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe):

2 []

PRODUCT DEPTH None

FT. BELOW DATUM

WATER DEPTH OTW: 8.58 TD: 15.8

FT. BELOW DATUM

4 []

WELL EVACUATION:

Method: Peristaltic Pump

Volume Removed:

Observations:

Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: hydrocarbon

Other comments: grey (slight) tint, clear

5 []

SAMPLE EXTRACTION METHOD:

☐ Bailer made of:

☒ Pump, type: Peristaltic

☐ Other, describe:

6 []

ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1001	1005	1010				Measured With
Temp (°C)	25.1	24.4	24.4				
pH	6.30	6.24	6.26				
Cond (µS/cm)	359	314	313				Haniba 11-10
Do (mg/L)	0.41	0.07	0.03				
Redox (mv)	-162.4	-168.0	-165.8				Hanna 9025
gallons purged	Initial	1 gal	2 gal				

Additional Comments:

7 []

SAMPLE CONTAINERS (material, number, size): 4-40ml VOAs (BTX, Benzene, Methane)

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina, AOC-A, SWMU 66, SWMU 64
Sampling Dates 6/23/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOCA-MWB-5
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 6/23, 1999 1420 a.m./p.m.
SAMPLE COLLECTED BY: BKB/BL of Parsons ES
WEATHER: Sunny
DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☐ LOCKED; ☒ UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: good
INNER PVC CASING CONDITION IS: good
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe):

2 [] PRODUCT DEPTH none FT. BELOW DATUM
WATER DEPTH 10.12 TO: 17.0 FT. BELOW DATUM

4 [] WELL EVACUATION:

Method: Peristaltic Pump
Volume Removed:
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: Hydrocarbon / Sulfur odor
Other comments:

5 [] SAMPLE EXTRACTION METHOD:

☐ Bailer made of:
☒ Pump, type: Peristaltic
☐ Other, describe:

6 [] ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1406	1411	1415	1421	1423	Measured With
Temp (°C)	25.3	24.9	24.8	24.8	24.7	
pH	5.37	5.19	5.29	5.54	5.58	
Cond (µS/cm)	75	78	103	136	147	Horiba U-10
Do (mg/L)	0.21	0.00/0.27	0.01/11	0.01/0.00	0.02	
Redox (mv)	-243.9	-209.8	-201.3	-186.6	-189.2	HI 9026 (HANNA)
gallons purged	Initial	1 gallon	2 gal	3 gal	4 gal	

Additional Comments:

7 [] SAMPLE CONTAINERS (material, number, size): 4 40ml / VOAS

BKB / MUSE, AGTHAW

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina, AOC-A, SWMU 66, SWMU 64
Sampling Dates 6/22/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOC A - MW-7
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 6/22/99, 1999 1115 a.m.
SAMPLE COLLECTED BY: BKB/BL of Parsons ES
WEATHER: mostly sunny
DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☐ LOCKED: ☒ UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: good
INNER PVC CASING CONDITION IS: good
WATER DEPTH MEASUREMENT DATUM (IS) IS NOT) APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe):

2 ☐ PRODUCT DEPTH NO FT. BELOW DATUM
WATER DEPTH 10.30 TD = 21.5 FT. BELOW DATUM

4 ☐ WELL EVACUATION:
Method: Peristaltic Pump
Volume Removed:
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: none
Other comments: brown, ran clear

5 ☐ SAMPLE EXTRACTION METHOD:
☐ Bailer made of:
☒ Pump, type: peristaltic
☐ Other, describe:

6 ☐ ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1055	1059	1103	1109		Measured With
Temp (°C)	23.1	22.9	22.9	22.9		Horiba U-10
pH	5.93	5.91	5.91	5.91		
Cond (µS/cm)	275	266	263	263		
Do (mg/L)	0.71	0.23	0.19	0.18		
Redox (mv)	53	70	70	71		VWR 3000
gallons purged	Initial	1 gal	2 gal	3 gal		

Additional Comments:

7 ☐ SAMPLE CONTAINERS (material, number, size): 4-40m VOA's
BTEX, MTBE, merlane

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina, AOC-A SWMU 66, SWMU 64
Sampling Dates 6/22

GROUND WATER SAMPLING RECORD - MONITORING WELL AOC A MWA-8
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 6/22/99, 1999 1250 a.m./p.m.
SAMPLE COLLECTED BY: BKB/BL of Parsons ES
WEATHER: Sunny
DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☒ LOCKED: ☐ UNLOCKED
WELL NUMBER (S) IS NOT APPARENT
STEEL CASING CONDITION IS: GOOD
INNER PVC CASING CONDITION IS: GOOD
WATER DEPTH MEASUREMENT DATUM (S) IS NOT APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe):

2 [] PRODUCT DEPTH ND FT. BELOW DATUM
WATER DEPTH 9.63' TD = 22' FT. BELOW DATUM

4 [] WELL EVACUATION:
Method: peristaltic
Volume Removed:
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: sulfur
Other comments: clear (slight coloration, very)

5 [] SAMPLE EXTRACTION METHOD:

☐ Bailer made of:
☒ Pump, type: peristaltic
☐ Other, describe:

6 [] ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1238	1242	1246				Measured With
Temp (°C)	27.0	26.9	26.9				Horiba U-10
pH	4.85	4.77	4.77				
Cond (µS/cm)	124	120	118				
Do (mg/L)	0.35	0.12	0.08				VWR 3000
Redox (mv)	139	139	138				
gallons purged	Initial	1 gal	2 gal				

Additional Comments:

7 [] SAMPLE CONTAINERS (material, number, size): 4-40ml VOA's (BTEX, MTBE, Methane)

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina, AOC-A SWMU 66, SWMU 64
Sampling Dates 6/22/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOC-A-MWA-9

(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: 6/22/99, 1999 1330 a.m.(p.m.)

SAMPLE COLLECTED BY: BKB/BL of Parsons ES

WEATHER: Sunny

DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☒ LOCKED:

☐ UNLOCKED

WELL NUMBER (~~IS~~ IS NOT) APPARENT

STEEL CASING CONDITION IS: good

INNER PVC CASING CONDITION IS: good

WATER DEPTH MEASUREMENT DATUM (~~IS~~ IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe):

2 ☐

PRODUCT DEPTH None

FT. BELOW DATUM

WATER DEPTH 10.42' TD = 23.2'

FT. BELOW DATUM

4 ☐

WELL EVACUATION:

Method: Peristaltic Pump

Volume Removed:

Observations: Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors:

Other comments:

5 ☐

SAMPLE EXTRACTION METHOD:

☐ Bailer made of:

☒ Pump, type: Peristaltic

☐ Other, describe:

6 ☐

ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1300	1305	1309	1312			Measured With
Temp (°C)	26.3	26.4	26.4	26.4			
pH	5.74	5.76	5.75	5.76			
Cond (µS/cm)	192	182	177	175			Horiba U-10
Do (mg/L)	0.49	0.02	0.01	0.00			
Redox (mv)	71	72	73	72			VWR 3000
gallons purged	Initial	1 gal	2 gal	2.5 gal			

Additional Comments:

7 ☐

SAMPLE CONTAINERS (material, number, size): 4-40ml VOA's (BTEX, MTBE, Methane)

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina, AOC-A, SWMU 66, SWMU 64
Sampling Dates 6/24/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOLA-MWD-11
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 6/24/99, 1999 0840 a.m.
SAMPLE COLLECTED BY: of Parsons ES
WEATHER: cloudy 75°F
DATUM FOR WATER DEPTH MEASUREMENT (Describe): TCL

MONITORING WELL CONDITION:

☐ LOCKED: ☒ UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: Good
INNER PVC CASING CONDITION IS: Good
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe):

2 ☐ PRODUCT DEPTH ND FT. BELOW DATUM
WATER DEPTH 8.90' TD = 21.3 FT. BELOW DATUM

4 ☐ WELL EVACUATION:

Method: Peristaltic Pump
Volume Removed:

Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors:
Other comments:

5 ☐ SAMPLE EXTRACTION METHOD:

☐ Bailer made of:
☒ Pump, type: Peristaltic
☐ Other, describe:

6 ☐ ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	0812	0820	0831	0840		Measured With
Temp (°C)	27.8	27.7	27.8	27.8		
pH	6.07	6.27	6.23	6.18		
Cond (µS/cm)	316	307	297	285		
Do (mg/L)	0.92	0.00	0.01	0.00		
Redox (mv)	-174.6	-177.5	-174.7	-162.1		
gallons purged	Initial	0 gal	9 gal	6 gal		

Additional Comments: AOLA-MWD-11 (Duplicate at 0930)

7 ☐ SAMPLE CONTAINERS (material, number, size):

8-40ml VOA sample & dup
BTEX, MTBE, methane

GROUNDWATER SAMPLING RECORD

Sampling Location AAFES, Marina (AOC-A) SWMU 66, SWMU 64
Sampling Dates 6/22/99

GROUND WATER SAMPLING RECORD - MONITORING WELL AOCA-mwA-13
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 6/22, 1999 1045 a.m./p.m.
SAMPLE COLLECTED BY: SKB/BK of Parsons ES
WEATHER: Mostly sunny
DATUM FOR WATER DEPTH MEASUREMENT (Describe): TOC

MONITORING WELL CONDITION:

☐ LOCKED: ☒ UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: good
INNER PVC CASING CONDITION IS: good
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe):

2 ☐ PRODUCT DEPTH None FT. BELOW DATUM
WATER DEPTH OTU: 10.87 TD: 22.1 FT. BELOW DATUM

4 ☐ WELL EVACUATION:
Method: Peristaltic Pump
Volume Removed:
Observations: Water (slightly very) cloudy
Water level (rose - fell - no change)
Water odors: none
Other comments: tan (slight)

5 ☐ SAMPLE EXTRACTION METHOD:
☐ Bailer made of:
☒ Pump, type: Peristaltic Pump
☐ Other, describe:

6 ☐ ON-SITE MEASUREMENTS:

DIRECT INSTRUMENT READINGS

Time	1024	1028	1033	1038	1043	Measured With
Temp (°C)	24.1	24.0	24.1	24.1	24.1	} Hach U-10
pH	5.99	5.77	5.70	5.69	5.69	
Cond (µS/cm)	209	179	169	164	164	
Do (mg/L)	0.33	0.07	0.04	0.04	0.00	} VVR 3000
Redox (mv)	75	80	88	92	91	
gallons purged	Initial	1 gal	2 gal	3 gal	4 gal	

Additional Comments:

7 ☐ SAMPLE CONTAINERS (material, number, size): 4- 40ml VOAs
BTEX, MTBE, Merlane

14

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE 6/23/99

TIME SAMPLED 1450

SAMPLE I.D. AOCA-MWB-1

TIME ANALYSIS START 1516

TIME ANALYSIS END 1527

FILTERED (circle) YES NO

COLOR / ODOR: clear / slight sulfur

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b}
Ferrous	50.01.1	0 - 5.10 mg/L	1	0.07	0.07 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	15.98	15.98 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia

0.6 ppm

Technician: BKB

^a sulfate blanks contain respective reagents;

Ferrous iron blanks are without reagents.

^b Ferrous iron blanks should be diluted accordingly if samples are diluted.

**ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES**

Keesler AFB

SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE

6/24/99

TIME SAMPLED

0952

SAMPLE I.D.

AOC-A MW8-3

TIME ANALYSIS START

1027

TIME ANALYSIS END

1037

FILTERED (circle)

YES

NO

COLOR / ODOR:

CLEAN / Sulfate 14.00 mg/L

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a, b/}
Ferrous	50.01.1	0 - 5.10 mg/L	1	1.00	mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	3.08	1.56 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia

1 ppm

Technician:

BL

^{a/} sulfate blanks contain respective reagents;

Ferrous iron blanks are without reagents.

^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

SULFATE w/o reagent 1.52

w/ reagent 3.08

21

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

~~Keesler AFB~~
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE

6/24/99

TIME SAMPLED

1015

TIME ANALYSIS START

1042

TIME ANALYSIS END

1105

SAMPLE I.D.

AOC-A-MWB-4

FILTERED (circle)

YES

NO

COLOR / ODOR: clear/hydrocarbon

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b}
Ferrous	50.01.1	0 - 5.10 mg/L	1	0.09	0.09 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	2.35	2.35 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia

2.0 ppm

Technician:

BKB

^{a/} sulfate blanks contain respective reagents;

Ferrous iron blanks are without reagents.

^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES
Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE 6/23/99 TIME SAMPLED 1420
SAMPLE I.D. AOCA-MWB-5 TIME ANALYSIS START 1500
TIME ANALYSIS END 1514

FILTERED (circle) YES NO

COLOR / ODOR: clear / Hydrocarbon smell

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b}
Ferrous	50.01.1	0 - 5.10 mg/L	1	0.18	0.18 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	1.56	1.56 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia 2.0 ppm

Technician: BKB

^{a/} sulfate blanks contain respective reagents;
Ferrous iron blanks are without reagents.
^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

6

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE

6/22/99

TIME SAMPLED

1115

TIME ANALYSIS START

1138

TIME ANALYSIS END

SAMPLE I.D.

AOCA-MHA-7

FILTERED (circle)

YES

NO

COLOR / ODOR:

clear /

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b}
Ferrous	50.01.1	0 - 5.10 mg/L	1	0.20	0.20 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	14.32	14.32 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia

0.1 ppm

Technician:

BKB

^a sulfate blanks contain respective reagents;

Ferrous iron blanks are without reagents.

^b Ferrous iron blanks should be diluted accordingly if samples are diluted.

3

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE 6/22/99

TIME SAMPLED 1250

SAMPLE I.D. AOLA-MNA-8

TIME ANALYSIS START 1330

TIME ANALYSIS END 1343

FILTERED (circle) YES NO

COLOR / ODOR: clear/sulfur

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a, b/}
Ferrous	50.01.1	0 - 5.10 mg/L	1	1.78	1.78 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	19.75	19.75 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia

1.0 ppm

Technician: BKB

^{a/} sulfate blanks contain respective reagents;

Ferrous iron blanks are without reagents.

^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE 6/22/99 TIME SAMPLED 1330
SAMPLE I.D. AOCA-MWA-9 TIME ANALYSIS START 1344
TIME ANALYSIS END 1400
FILTERED (circle) YES NO
COLOR / ODOR: clear/sulfur

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b/}
Ferrous	50.01.1	0 - 5.10 mg/L	1	0.17	0.17 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	2.05	2.05 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:
Ammonia

0.4 ppm

Technician: BKB

^{a/} sulfate blanks contain respective reagents;
Ferrous iron blanks are without reagents.
^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE 6/24/99

TIME SAMPLED 0840

SAMPLE I.D. AOC-A-MWA-11

TIME ANALYSIS START 0910

TIME ANALYSIS END

FILTERED (circle) YES NO

COLOR / ODOR: clear / hydrocarbon

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b/}
Ferrous	50.01.1	0 - 5.10 mg/L	1	0.49	0.49 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	35.48	35.48 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:

Ammonia 2.0 ppm

Technician: BKB

^{a/} sulfate blanks contain respective reagents;

Ferrous iron blanks are without reagents.

^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

* RAW SULFIDE > 0.600 mg/L
indicates sulfate reduction

ON-SITE MEASUREMENTS
HACH AND CHEMetrics ANALYSES

Keesler AFB
SWMU 66 AOC-A AAFES MARINA

SAMPLE DATE 6/22/99 TIME SAMPLED 1045
SAMPLE I.D. AOC-A-MWA-13 TIME ANALYSIS START 1127
TIME ANALYSIS END 1137

FILTERED (circle) YES NO

COLOR / ODOR: clear

HACH DR/700 Measurements:

Analyte	Program	Range	Dilution	Reading	Concentration	Blank ^{a,b}
Ferrous	50.01.1	0 - 5.10 mg/L	1	1.35	1.35 mg/L	sample
					mg/L	sample
Sulfate	45.000	0 - 100 mg/L	1	15.25	15.25 mg/L	DI or 50mg/L
					mg/L	DI or 50mg/L

CHEMetrics Color Tests:
Ammonia

0.2 ppm

Technician: BKB

^{a/} sulfate blanks contain respective reagents;
Ferrous iron blanks are without reagents.
^{b/} Ferrous iron blanks should be diluted accordingly if samples are diluted.

APPENDIX C
DATA VALIDATION SUMMARY

APPENDIX C
DATA EVALUATION SUMMARY
AREA OF CONCERN A
KEESLER AFB
JUNE 1999

INTRODUCTION

Nine environmental groundwater samples and one water field duplicate sample were collected from Area of Concern A (AOC A) at Keesler AFB in Mississippi between June 22 and 24, 1999. The samples were sent to Specialized Assays in Nashville, Tennessee for analysis of BTEX/MTBE by Method 8021B and methane by Method RSK175M. Data validation was performed by Parsons ES for all sample results in accordance with the requirements contained in the USEPA *National Functional Guidelines for Data Review* (1994).

DATA VALIDATION

The following summarizes the analysis specific laboratory QC elements reviewed during data validation.

Volatile Organic Compounds by Method 8021B

- Holding Times
- Method Blanks
- Field Blanks
- Surrogate Recoveries
- Laboratory Control Spike Recoveries
- Matrix Spike/Matrix Spike Duplicate Recoveries and Relative Percent Difference
- Field Duplicate Precision
- Project Reporting Limits

Methane by Method RSK175M

- Holding Times
- Method Blanks
- Field Blanks
- Surrogate Recoveries
- Laboratory Control Spike Recoveries
- Matrix Spike/Matrix Spike Duplicate Recoveries and Relative Percent Difference
- Field Duplicate Precision
- Project Reporting Limits

Field blanks consist of one trip blank collected on June 24, 1999 and analyzed for volatile organics and methane. This trip blank was associated with all samples. There was no contamination present in the trip blank. The laboratory provided batch QC results for matrix spike/matrix spike duplicate (MS/MSD) samples. The field blank and QC sample results were evaluated to determine the effect, if any, the field sampling efforts and/or the matrix had on the accuracy, precision and representativeness of the environmental sample results. Client sample identifications were not reported for the MS/MSD samples. The samples may or may not have been samples from Keesler AFB. No qualification of samples was performed based solely on the MS/MSD results since a site matrix evaluation could not be performed.

The following describes the data qualifiers assigned by the data validator as a result of the review and evaluation of both the laboratory QC elements and the field QC samples.

J - The analyte was analyzed for and was positively identified but the associated numerical value may not be consistent with the amount actually present in the environmental sample. The data should be seriously considered for decision-making and are useable for many purposes.

These items were considered compliant and acceptable in accordance with the evaluation protocols with qualifications as noted below.

VOLATILE ORGANICS (METHOD 8021) - FIELD DUPLICATE

All relative percent differences were within acceptance criteria with the following exceptions:

<u>Compound</u>	<u>Concentration (µg/L)</u>			<u>QC Limit</u>
	<u>MWA-11</u>	<u>MWD-11</u>	<u>RPD</u>	
toluene	98.4	79.5	21.2	20

The sample results for toluene were considered estimated and flagged "J" in the field duplicate pair.

METHANE (METHOD RSK175M) - FIELD DUPLICATE

All relative percent differences were within acceptance criteria with the following exceptions:

<u>Compound</u>	<u>Concentration (mg/L)</u>			<u>QC Limit</u>
	<u>MWA-11</u>	<u>MWD-11</u>	<u>RPD</u>	
methane	258	173	39.4	20

The sample results for methane were considered estimated and flagged "J" in the field duplicate pair.

DATA USABILITY

Following the data validation, the results of the laboratory QC analyses and procedures, the field QC samples, and the investigative samples were reviewed. The purpose of this review was to provide an assessment of the overall data quality and usability of the data. The following sections summarize the results of the data quality assessment (DQA) review.

Review of the Laboratory Data

The results of the field QC samples were evaluated to determine the affect, if any, the field sampling efforts and/or the matrix had on the accuracy, precision and representativeness of the environmental sample results. The frequency of the QC samples was one MS/MSD pair for every twenty investigative samples and one field duplicate for every fifteen investigative samples. The project required MS/MSD and field duplicate frequencies were met.

Percent completeness is the percent of the planned sample data that is not qualified as "R" during the data validation process and is considered to be useable for decision making purposes. The target percent completeness is 90% for each sample analysis. No sample results were considered rejected or unusable, therefore, the percent completeness for all analyses was 100%.

CONCLUSIONS

The data for samples collected from AOC A at Keesler AFB is useable as qualified. The precision, accuracy, representativeness, comparability and completeness goals were met. There was no adverse impact either the overall data quality or usability for decision making for Keesler AFB.

APPENDIX D
CONTAMINANT ATTENUATION ASSESSMENT

APPENDIX D

CONTAMINANT ATTENUATION ASSESSMENT

FACILITY 1504 AND AOC-A

D.1 INTRODUCTION

Biodegradation of dissolved fuel constituents is assessed in this section to support selection of a long term management (LTM) approach for sites at the base service station: Facility 1504 and Area of Concern -A (AOC-A). As used throughout this report, the term "remediation by natural attenuation" (RNA) refers to a subsurface contaminant management strategy that relies on natural physical, chemical, and biological mechanisms to control exposure of potential receptors to concentrations of contaminants in soil and groundwater that exceed regulatory levels. These mechanisms include the processes of hydrodynamic dispersion, dilution, sorption, volatilization, and biodegradation, which facilitate RNA of a variety of anthropogenic chemicals.

This section summarizes and interprets specific site characterization data relevant to documenting the effectiveness of RNA by:

1. Discussing different attenuation mechanisms (Section D.2);
2. Assessing evidence of contaminant attenuation over time (Section D.3); and
3. Analyzing geochemical data collected during the June 1999 field effort (Sections D.4 and D.5)

D.2 OPERATIVE MECHANISMS OF CONTAMINANT ATTENUATION

Understanding the fate of fuel hydrocarbons in environmental media is critical to evaluating and predicting contaminant distribution patterns. There are several physical, chemical, and biological processes that influence how a chemical behaves in soil and groundwater.

Nondestructive attenuation processes can be described as those physical and chemical processes that may prohibit significant contaminant migration but will not result in a permanent reduction in contaminant mass. Examples of nondestructive attenuation processes include volatilization, sorption, dilution, and hydrodynamic dispersion. These processes must be evaluated when determining whether some type of remediation is warranted because chemical contamination poses or has the potential to pose a risk to

human or ecological receptors. If contamination cannot reach a potential receptor exposure point, the contamination poses no risk.

In comparison to nondestructive chemical attenuation processes, destructive chemical attenuation processes result in the permanent removal of contaminant mass from the environment. Documenting and distinguishing the effects of destructive attenuation processes, such as biodegradation, from nondestructive attenuation processes is critical to evaluating the potential for RNA to bring about a reduction in contaminant mass over time. The effectiveness of destructive attenuation processes at reducing contaminant mass at a site depends on how susceptible the chemical is to biodegradation and whether the site is characterized by physical, chemical, and biological conditions favorable to such processes.

D.3 EVIDENCE OF CONTAMINANT BIODEGRADATION OVER TIME

The first step in determining whether fuel hydrocarbon constituents are biodegrading in soils and groundwater at Facility 1504 and AOC-A was to compare contaminant concentrations at selected sampling locations over time. The purpose of this comparison was to assess the evidence of field-scale contaminant mass loss. Decreases in the magnitude of contaminant concentrations at a site over time that cannot be explained by physical processes (e.g., source removal, mass transport in groundwater) may be the first indication that contaminants are biodegrading at the site.

D.3.1 Hydrocarbon Concentration Trends in Soil

Biodegradation of soil hydrocarbons present in the vadose zone can proceed if the soil particles to which the contaminants are adsorbed are covered with a water film that supports microbial populations. The presence of abundant soil moisture in the vadose zone can be inferred from the shallow water table depth, the relatively warm ambient air temperature, and the presence of the asphalt/concrete cap over much of the site that would inhibit evaporation of subsurface moisture into the atmosphere. Comparison of soil data from April 1995 to September 1998 indicated the maximum BTEX concentration decreased in the soil (Parsons, 1999 and Parsons ES, 1998b). No soil samples were collected in the 1999 sampling event.

D.3.2 Hydrocarbon Concentration Trends in Groundwater

Hydrocarbon concentrations were measured from five monitoring wells at Facility 1504 in 1995, 1998, and 1999 and from nine monitoring wells at AOC-A in 1992, 1998, and 1999; the data are summarized in Tables D.1 and D.2, respectively. Within Facility 1504, four of the five wells had total BTEX concentrations that decreased or were consistently below detection limits. MW-5 and MW-8 increased slightly from 1998 to 1999, but were still lower than the 1995 total BTEX concentrations. MW-7 increased

substantially from 2.5 µg/L in 1998 to 126 µg/L in 1999 and can be attributed to the mass transport of the plume in the groundwater.

Total BTEX concentrations within AOC-A decreased substantially or remained below detection limits at five of the nine locations. The maximum BTEX concentration in 1998 of 22,400 µg/L at MW8-3 decreased to 3,694 µg/L in 1999. BTEX concentrations at MW8-5 steadily increased from 272 µg/L in 1992 to 3,063 µg/L in 1999. Monitoring wells MWA-7 and MWA-13, which are on the down gradient edge of the plume increased slightly from non-detect to 6.8 and 10.4 µg/L, respectively.

Decreasing dissolved hydrocarbon concentrations indicate that the mass of hydrocarbons input into the groundwater system in the source area (through leaching of residual hydrocarbons in soils) is decreasing, and that biodegradation of dissolved BTEX is occurring.

D.4 EVIDENCE OF CONTAMINANT BIODEGRADATION VIA MICROBIALY MEDIATED REDOX REACTIONS

Groundwater geochemical data also can be used to show that fuel hydrocarbons are biodegrading in saturated soil and groundwater at Facility 1504 and AOC-A. Fuel hydrocarbon constituents are typically utilized as electron donors in biologically mediated redox reactions under a wide range of geochemical conditions. Therefore, analytical data on potential electron acceptors can be used as geochemical indicators of fuel hydrocarbon biodegradation (Wiedemeier *et al.*, 1995). Reductions in the concentrations of oxidized chemical species that are used by microorganisms to facilitate the oxidation of fuel hydrocarbon compounds within contaminated media are an indication that contaminants are biodegrading. Alternately, an increase in the metabolic byproducts resulting from the reduction of electron acceptors can be used as an indicator of contaminant biodegradation. The availability of potential electron acceptors to participate in contaminant biodegradation reactions can be used to estimate the total contaminant mass that can be biodegraded over time at this site. Coupled with calculated biodegradation rates, this information can be used to predict how much and how quickly fuel hydrocarbons can be removed from saturated soils and groundwater at Facility 1504 and AOC-A as a result of natural processes only.

D.4.1 Relevance of Redox Couples in Biodegradation

Microorganisms obtain energy to replenish enzymatic systems and to reproduce by oxidizing organic matter. Biodegradation of dissolved hydrocarbons is the result of a series of redox reactions that maintain the charge balance within the natural environment. Microorganisms facilitate the degradation of these organic compounds by transferring electrons from the electron donor (i.e., fuel hydrocarbons and native organic carbon) to available electron acceptors. Electron acceptors are elements or compounds that occur in relatively oxidized states and can participate in redox reactions involving these available

electron donors. Electron acceptors known to be present in saturated soil and groundwater at Facility 1504 and AOC-A are oxygen, nitrate/nitrogen, sulfate, ferric iron (Fe^{3+}), and carbon dioxide.

Microorganisms facilitate fuel hydrocarbon biodegradation to produce energy for their use. The amount of energy that can be released when a reaction occurs or is required to drive the reaction to completion is quantified by the free energy of the reaction (Stumm and Morgan, 1981). Microorganisms are able to utilize electron transport systems and chemiosmosis to combine energetically favorable and unfavorable reactions to produce energy for life processes (i.e., cell production and maintenance). Microorganisms will facilitate only those redox reactions that will yield energy. By coupling the oxidation of fuel hydrocarbon compounds, which requires energy, to the reduction of other compounds (e.g., oxygen, nitrate/nitrite, manganese, ferric iron, sulfate, and carbon dioxide), which yields energy, the overall reaction will yield energy. Detailed information on the redox reactions required to biodegrade dissolved fuel hydrocarbons is included in Table D.3. The reader is encouraged to review this information to more fully understand the chemical basis of biodegradation.

Figure D.1 illustrates the sequence of microbially mediated redox processes based on the amount of free energy released for microbial use. In general, reactions yielding more energy tend to take precedence over processes that yield less energy (Stumm and Morgan, 1981). As Figure D.1 shows, oxygen reduction would be expected to occur in an aerobic environment with microorganisms capable of aerobic respiration because oxygen reduction yields significant energy. However, once the available oxygen is depleted and anaerobic conditions dominate the interior regions of the contaminant plume, anaerobic microorganisms can utilize other electron acceptors in the following order of preference: nitrate/nitrite, manganese, ferric iron, sulfate, nitrogen, and carbon dioxide. Each successive redox reaction provides less energy to the system, and each step down in redox energy yield would have to be paralleled by an ecological succession of microorganisms capable of facilitating the pertinent redox reactions.

The expected sequence of redox processes can be estimated by the oxidation-reduction potential (ORP) of the groundwater. The ORP measures the relative tendency of a solution or chemical reaction to accept or transfer electrons, and can be measured in the field. This measurement can be used as a crude indicator of which redox reactions may be operating at a site. High ORPs mean that the solution (or available redox couple) has a relatively high oxidizing potential.

Microorganisms can only facilitate the biodegradation (oxidation) of the fuel hydrocarbon compounds using redox couples that have a higher ORP than the contaminants. This is why these electron acceptors can be used to oxidize the fuel hydrocarbon compounds. The reduction of highly oxidized species results in an overall decrease in the oxidizing potential of the groundwater. As shown in Figure D.1, the

reduction of oxygen and nitrate will reduce the oxidizing potential to levels at which ferric iron reduction can occur. As each chemical species that can be used to oxidize the contaminants is exhausted, the microorganisms are forced to use other available electron acceptors with lower oxidizing capacity. When sufficiently low (negative) ORP levels have developed as a result of these redox reactions, sulfate reduction, methanogenesis, and nitrogen fixation can occur almost simultaneously (Stumm and Morgan, 1981).

ORP values measured in shallow groundwater at Facility 1504 and AOC-A in June 1999 ranged from -110.0 to -189.2 millivolts (mV) (Table D.4, Figure D.2). Because of a faulty ORP meter, this range includes only six of the fourteen monitoring wells sampled. Areas with the lowest ORPs generally coincided with the presence of fuel-contaminated groundwater, indicating that the progressive use of electron acceptors in the order shown on Figure D.1 has caused the groundwater in the contaminated areas to become more reducing. These data imply that oxygen, nitrate, manganese, and ferric iron may be used to biodegrade fuel hydrocarbon contaminants at this site. However, many authors have noted that field ORP data alone cannot be used to reliably predict all of the electron acceptors that may be operating at a site, because the platinum electrode probes of ORP meters are not sensitive to some redox couples (e.g., sulfate/sulfide) (Stumm and Morgan, 1981; Godsy, 1994; Lovley *et al.*, 1994). Analytical data on oxidized and reduced species are presented in the following subsections to verify which electron acceptors are actually being used to biodegrade the hydrocarbon fuel hydrocarbons in saturated soil and groundwater at Facility 1504 and AOC-A.

Throughout the following subsections, the distributions of geochemical parameters are examined by comparing background concentrations to fuel hydrocarbon plume core concentrations. Analytical data from upgradient well MW-2 is used for background concentrations. Analytical data from MW-8, MW8-3, MW8-4, and MW8-5 are used for fuel hydrocarbon plume core concentrations. Hydrocarbon concentrations are presented in Section 3 on Figures 3.3 and 3.4. The following qualitatively indicates the expected geochemical parameter response to biodegradation of BTEX compounds, with ↑ referring to relatively high concentrations and ↓ referring to relatively low concentrations (Payne, *et al.* 1995):

BTEX ↑: O_2 ↓ NO_3^- ↓ NH_3 ↑ Fe^{2+} ↑ SO_4^{4-} ↓ H_2S ↑ CH_4 ↑

BTEX ↓: O_2 ↑ NO_3^- ↑ NH_3 ↓ Fe^{2+} ↓ SO_4^{4-} ↑ H_2S ↓ CH_4 ↓

D.4.2 Dissolved Oxygen (O_2)

Almost all types of fuel hydrocarbons can be biodegraded under aerobic conditions (Borden, 1994). Mineralization of fuel hydrocarbons to carbon dioxide and water under aerobic conditions involves the use of oxygen as a cosubstrate during the initial stages of metabolism, and as a terminal electron acceptor during the later stages of metabolism for energy production. The reduction of molecular oxygen during the oxidation of the fuel

hydrocarbon compounds yields a significant amount of free energy that the microorganisms can utilize.

DO concentrations were measured at groundwater sampling locations in June 1999. The analytical results for DO by sampling location are presented in Tables D.4 and D.5. As shown on the table, DO concentrations range from 0.00 to 0.18 mg/L. The overall low magnitude of DO concentrations indicates that oxygen is not currently a significant electron acceptor during microbially mediated degradation of fuel hydrocarbons at Facility 1504 and AOC-A. However, a periodic contribution to dissolved oxygen from rainfall can be expected.

D.4.3 Ammonia (NH_3)

The presence of ammonia in groundwater can result from either nitrate reduction (facilitated by microbes) or fixing of atmospheric nitrogen (also a microbial process). From previous sampling events at Facility 1504 and AOC-A, we know nitrate is not widespread in groundwater within the surficial aquifer; however, the fixation of atmospheric nitrogen may occur under the anaerobic, methanogenic conditions observed at the site. The presence of ammonia in groundwater is a strong indication of microbial activity.

Ammonia (as N) concentrations measured in groundwater samples collected in June 1999 are summarized in Tables D.4 and D.5, and presented on Figure D.3. The background ammonia concentration measured in well MW-2 was 0.1 mg/L. In contrast, the ammonia concentration detected in the plume core well exhibiting one of the highest contaminant concentrations (MW-8) was 2 mg/L (Tables D.4 and D.5, Figure D.4). Ammonia concentrations detected in shallow groundwater varied across the site, with elevated ammonia concentrations occurring in the fuel hydrocarbon plume core area. Therefore, production of ammonia appears to be occurring due to increased microbial activity stimulated by the relative abundance of organic carbon (fuel hydrocarbons).

The measured ORPs of the groundwater at this site are not within the range that would be expected for the ammonia-producing conditions implied by the observed ammonia distribution. However, as described in Section D.4.1, field ORP data alone cannot be used to reliably predict the electron acceptors that may be operating at a site.

D.4.4 Ferrous Iron (Fe^{2+})

Although relatively little is known about the anaerobic metabolic pathways involving the reduction of ferric iron (Fe^{3+}), this process has been shown to be a major metabolic pathway for some microorganisms (Lovley and Phillips, 1988; Chapelle, 1993). Elevated concentrations of ferrous iron (Fe^{2+}) often are found in anaerobic, fuel-contaminated groundwater systems. Concentrations of dissolved ferrous iron once were attributed to the spontaneous and reversible reduction of ferric oxyhydroxides, which are thermodynamically unstable in the presence of organic compounds such as benzene.

However, more recent studies suggest that the reduction of ferric iron cannot proceed at all without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993). None of the common organic compounds found in low-temperature, neutral, reducing groundwater could reduce ferric oxyhydroxides to ferrous iron under sterile laboratory conditions (Lovley *et al.*, 1991). This means the reduction of ferric iron to ferrous iron requires mediation by microorganisms with the appropriate enzymatic capabilities.

To determine if ferric iron is being used as an electron acceptor for fuel biodegradation at Facility 1504 and AOC-A, ferrous (reduced) iron concentrations were measured at groundwater sampling locations in June 1999. The background ferrous iron concentration measured in well MW-2 was 0.19 mg/L. In contrast, the ferrous iron concentration detected in the plume core well exhibiting the highest contaminant concentrations (MW-8) was 1.89 mg/L (Tables D.4 and D.5, Figure D.4). The occurrence of elevated ferrous iron concentrations within contaminated areas indicates that ferric iron is acting as an electron acceptor at these locations. In addition, the measured redox potentials of the groundwater at this site are within the range that would be expected for the ferric iron-reducing conditions implied by the observed ferrous iron distributions (Figure D.1).

D.4.5 Sulfate (SO_4^{2-})

Sulfate also may be used as an electron acceptor during microbial degradation of fuel hydrocarbons under anaerobic conditions (Grbic'-Galic', 1990). Sulfate can be reduced to sulfide (H_2S) during the oxidation of the fuel hydrocarbon compounds. The presence of decreased concentrations of sulfate (and increased concentrations of sulfide) in the source area relative to background concentrations indicates that sulfate is participating in redox reactions at the site. To investigate the potential for sulfate reduction at Facility 1504 and AOC-A, sulfate concentrations were measured during the June 1999 groundwater sampling event.

Tables D.4 and D.5, and Figure D.5 show the analytical results for sulfate in groundwater at Facility 1504 and AOC-A. The background sulfate concentration measured in well MW-2 was 29.67 mg/L. In contrast, the sulfate concentration detected in the plume core well exhibiting the lowest contaminant concentrations (MW-8) was 0.68 mg/L (Tables D.4 and D.5, Figure D.4). There is a good correlation between areas of depleted sulfate concentrations and the plume core. The decrease of sulfate within the contaminated area indicates microbial populations are using sulfate to oxidize fuel hydrocarbons at the site.

D.4.6 Dissolved Methane (CH_4)

The carbon dioxide/methane (CO_2/CH_4) redox couple also could be used to oxidize fuel hydrocarbon compounds to carbon dioxide and water once the groundwater is

sufficiently reducing. To attain these reducing levels, other highly oxidizing chemical species such as oxygen, nitrate, ferric iron, and sulfate must first be reduced. This redox reaction is called methanogenesis or methane fermentation. Methanogenesis yields the least free energy to the system in comparison to other chemical species (Figure D.1). The presence of methane in groundwater at elevated concentrations relative to background concentrations is a good indicator of methane fermentation.

Dissolved methane was measured at groundwater monitoring wells sampled during the June 1999 sampling event. Tables D.4 and D.5, and Figure D.6 present the analytical data for methane. Methane concentrations detected in the contaminant source areas were elevated relative to background concentrations. Methane concentrations measured at plume core area wells ranged from 1.78 mg/L (MW-8) to 4.49 mg/L (MW8-4). In contrast, the background concentration was below detection limits (<0.026 mg/L). The presence of elevated methane levels in groundwater at Facility 1504 and AOC-A strongly indicates biodegradation is occurring via methanogenesis.

The measured ORPs of the groundwater at this site are not within the range that would be expected for the methanogenic conditions implied by the observed methane distributions. However, as described in Section D.4.1, field ORP data alone cannot be used to reliably predict the electron acceptors that may be operating at a site.

D.4.7 pH

The pH of groundwater samples collected from groundwater monitoring wells in June 1999 was measured (Tables D.4 and D.5). The pH of a solution is the negative logarithm of the hydrogen ion concentration $[H^+]$. Groundwater pH values measured at the site ranged from 4.77 to 6.38 standard units (SU) with an average of 5.79 SU. This average pH is slightly below the optimal range for fuel hydrocarbon-degrading microbes of 6 to 8 SU. The presence of acidic pH values indicates groundwater alkalinity may be insufficient to fully buffer the groundwater pH against the organic acids produced during microbial reactions.

D.5 THEORETICAL ASSIMILATIVE CAPACITY ESTIMATES

The preceding discussions have been devoted to determining if fuel hydrocarbons are biodegrading in saturated soils and groundwater at Facility 1504 and AOC-A. Analytical data on reduced and oxidized chemical species indicate indigenous microorganisms are facilitating the oxidation of fuel hydrocarbons and the reduction of electron acceptors to generate free energy for cell maintenance and production. The question of how much contaminant mass can be biodegraded must be addressed to assess the full potential for long-term intrinsic bioremediation to minimize plume size and mass over time.

Mass balance relationships can be used to determine how much contaminant mass can be degraded by each of the redox reactions that the microorganisms might use to make

free energy available for cell maintenance and production. The stoichiometric relationship between the contaminant and the electron acceptor can be used to estimate the expressed assimilative capacity of the groundwater. Once the redox reactions operating at the site have been defined, it is possible to estimate how much contaminant mass can be assimilated or oxidized by available electron acceptors.

Table D.3 presents the coupled redox reactions that represent the biodegradation of the individual fuel hydrocarbons, including the stoichiometric mass ratio of electron acceptors needed to oxidize each compound. These stoichiometric mass ratios can be used to estimate the assimilative capacity of the groundwater at Facility 1504 and AOC-A. For oxygen, nitrate, and sulfate (which are electron acceptors), this is accomplished by first determining the initial (background) mass of each electron acceptor available in the groundwater. Data on these chemical species were collected at sampling locations upgradient from the dissolved plume. As groundwater slowly migrates into the source area, electron acceptors are brought into contact with hydrocarbon-degrading microorganisms and site contamination. The change in the electron acceptor mass from background sampling locations to sampling locations within the plume core is divided by the mass ratio from Table D.3.

For nitrogen fixation, ferric iron reduction, and methanogenesis, the electron acceptor is not measured. Instead, the metabolic byproducts (ammonia, ferrous iron, and methane) are measured. The highest observed concentration of the metabolic byproduct in the plume core wells is divided by the mass ratio from Table D.3. These numbers are summed to estimate the expressed intrinsic capacity of the groundwater to biodegrade fuel hydrocarbons (Table D.6).

On the basis of these calculations, one pore volume of saturated soil and groundwater at Facility 1504 and AOC-A has the capacity to oxidize an average BTEX concentration of approximately 13.03 mg/L (13,030 µg/L) (Table D.6). The maximum BTEX concentration at Facility 1504 and AOC-A in June 1999 was 23.76 mg/L (23,760 µg/L).

This estimate essentially represents an estimate of the fuel hydrocarbon reduction capability of one pore volume of groundwater at Facility 1504 and AOC-A. The estimate identifies how much contaminant mass can be theoretically oxidized as one pore volume travels through the plume core. In reality, one pore volume is expected to move through the contaminated aquifer material in the source area every 3.45 years based on the estimated groundwater velocity of 292 ft/yr and a source area length of approximately 1008 feet.

A closed system containing 2 liters of water can be used to help visualize the physical meaning of assimilative capacity. Assume that the first liter contains no fuel hydrocarbons, but it contains fuel-degrading microorganisms and has an assimilative capacity of exactly "x" mg of fuel hydrocarbons. The second liter has no assimilative capacity; however, it

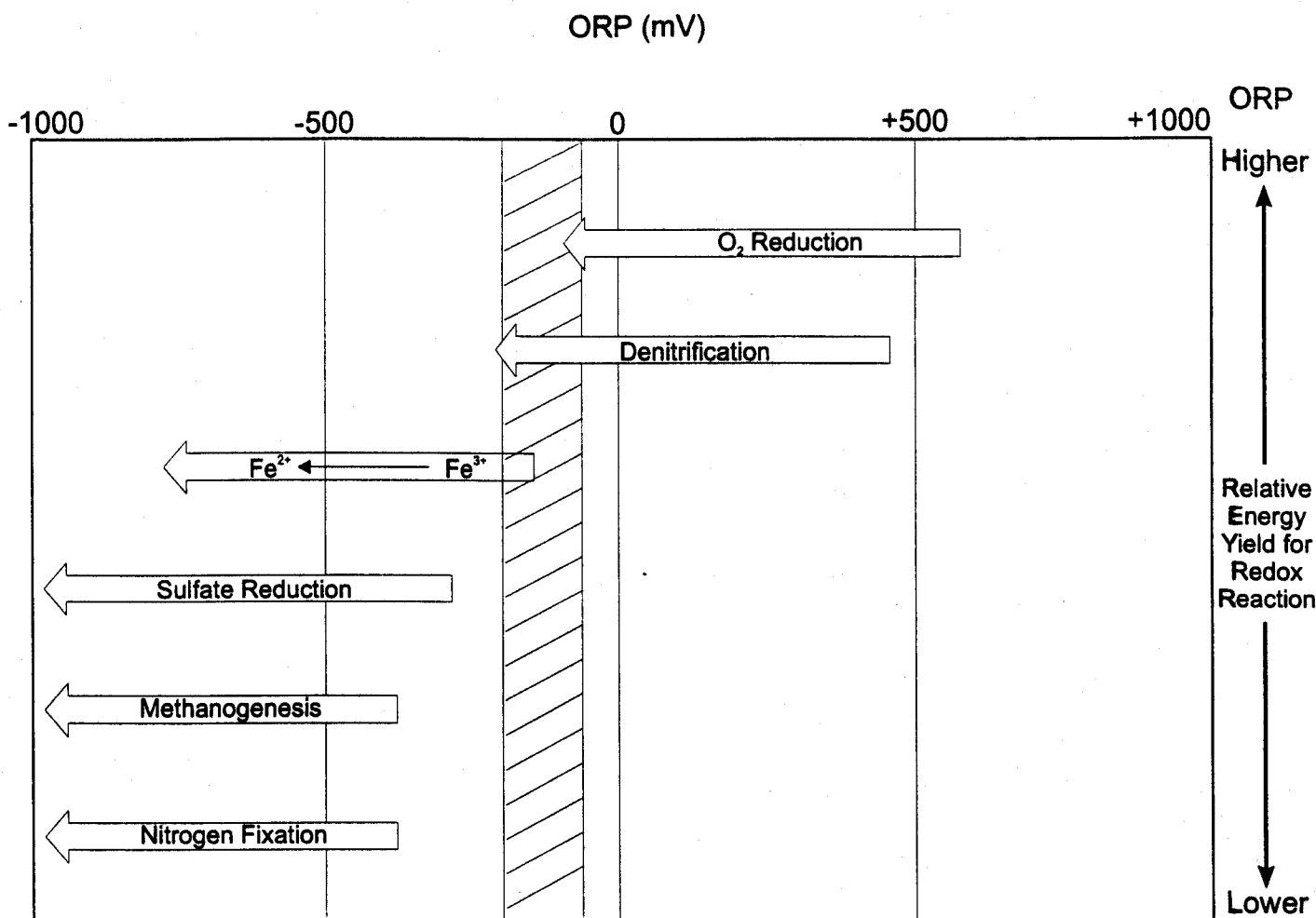
contains fuel hydrocarbons. As long as these 2 liters of water are kept separate, biodegradation of fuel hydrocarbons will not occur. If these 2 liters are combined in a closed system, biodegradation will commence and continue until the fuel hydrocarbons or electron acceptors are depleted. If less than "x" mg of fuel hydrocarbons are in the second liter, all of the fuel hydrocarbons will eventually degrade given a sufficient time; likewise, if greater than "x" mg of fuel hydrocarbons were in the second liter of water, only "x" mg of fuel hydrocarbons would ultimately degrade.

This example shows that in a closed system, the measured expressed assimilative capacity eventually should be equivalent to the loss in contaminant mass; however, the groundwater beneath the site is an open system. Electron acceptors can continually enter the system from upgradient flow. Furthermore, contaminant mass can be added to the system through dissolution or leaching from contaminated soils. This means that the assimilative capacity is not fixed as it would be in a closed system, and therefore should not be quantitatively compared to concentrations of dissolved contaminants in the groundwater. Rather, the expressed assimilative capacity of groundwater is intended to serve as a qualitative tool. The fate of fuel hydrocarbons in groundwater is dependent on the relationship between the kinetics of biodegradation and the solute transport velocities (Chapelle, 1994).

D.6 SUMMARY OF FINDINGS

The results of chemical fate assessment performed in this section are as follows:

1. Historical groundwater analytical data indicate that BTEX concentrations are decreasing over time;
2. Geochemical data strongly indicate that biodegradation of fuel hydrocarbons is occurring primarily through the processes of iron reduction, sulfate reduction, nitrogen fixation, and methanogenesis; and
3. The expressed BTEX assimilative capacity of the aquifer (13.03 mg/L) is less than the maximum BTEX concentration detected in Facility 1504 and AOC-A groundwater (23.76 mg/L).



Notes

ORP = Oxidation Reduction Potential

 Range of ORP measured at Facility 1504 / AOC-A

1. These reactions would be expected to occur in sequence if the system is moving toward equilibrium.
2. These redox processes occur in order of their energy-yielding potential (provided microorganisms are available to mediate a specific reaction). Reduction of a highly oxidized species decreases the ORP of the system.
3. The ORP of the system determines which electron acceptors are available for organic carbon oxidation.
4. Redox reaction sequence is paralleled by an ecological succession of biological mediators.

FIGURE D.1

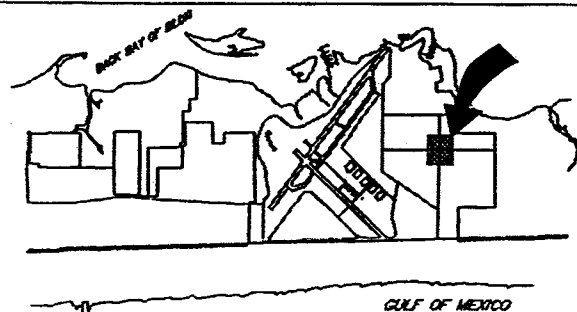
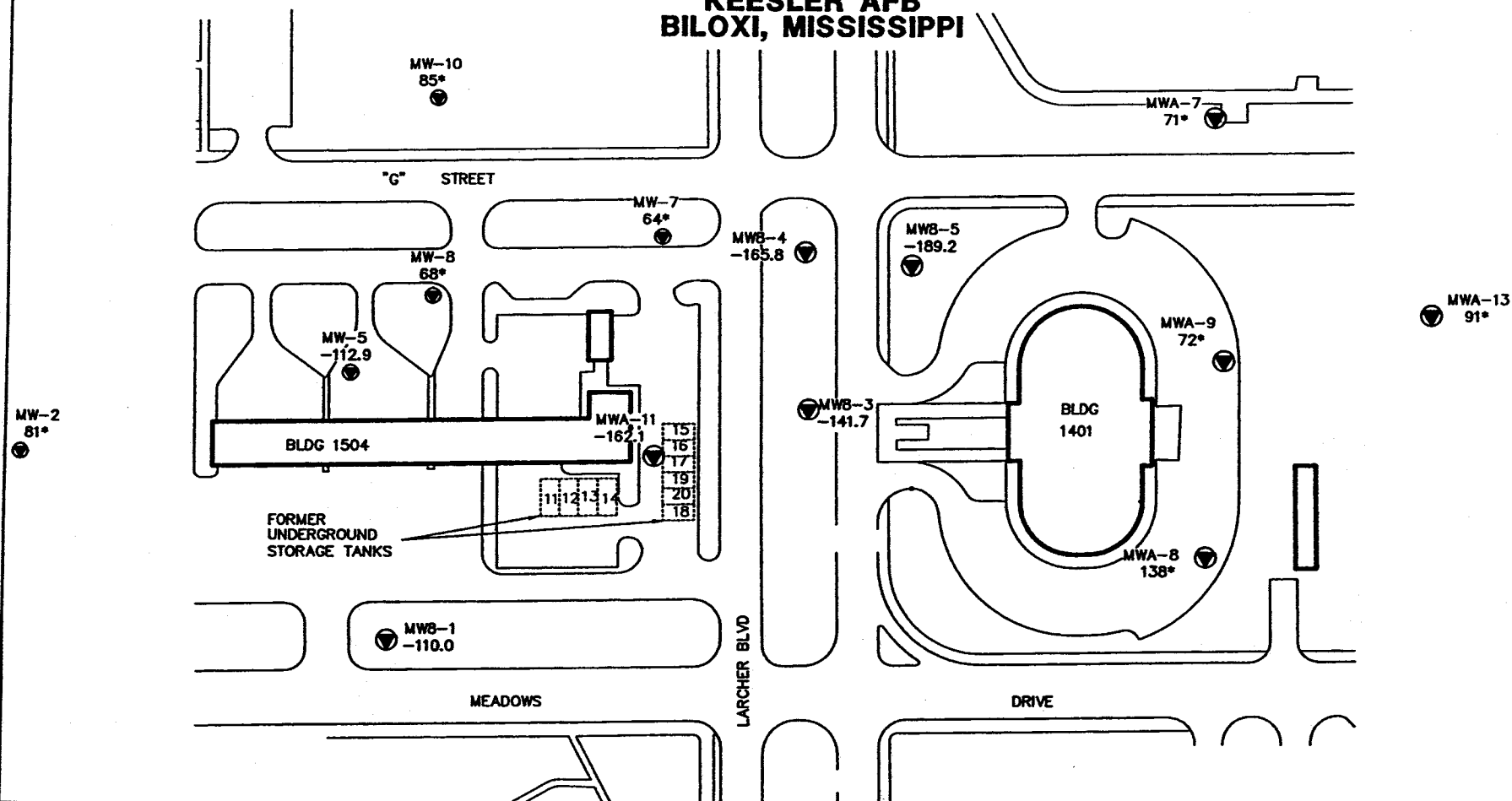
SEQUENCE OF MICROBIALY MEDIATED REDOX PROCESSES

Risk-Based Approach to Remediation
Facility 1504 / AOC-A
Keesler AFB, Mississippi

**PARSONS
ENGINEERING SCIENCE, INC.**

Atlanta, Georgia

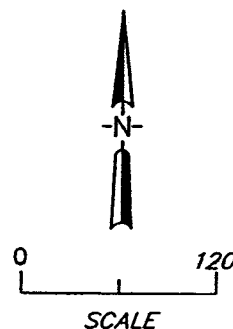
**FIGURE D.2
DISTRIBUTION OF OXIDATION REDUCTION POTENTIAL IN GROUNDWATER
FACILITY 1504 AND AOC-A
KEESLER AFB
BILOXI, MISSISSIPPI**



KEY MAP

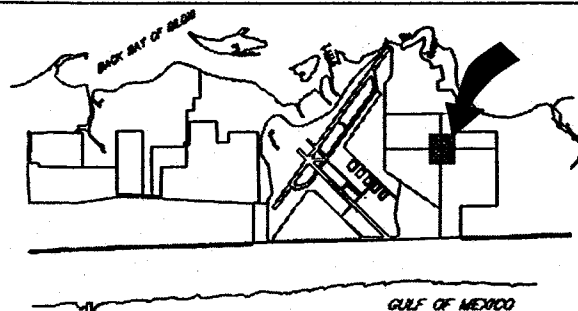
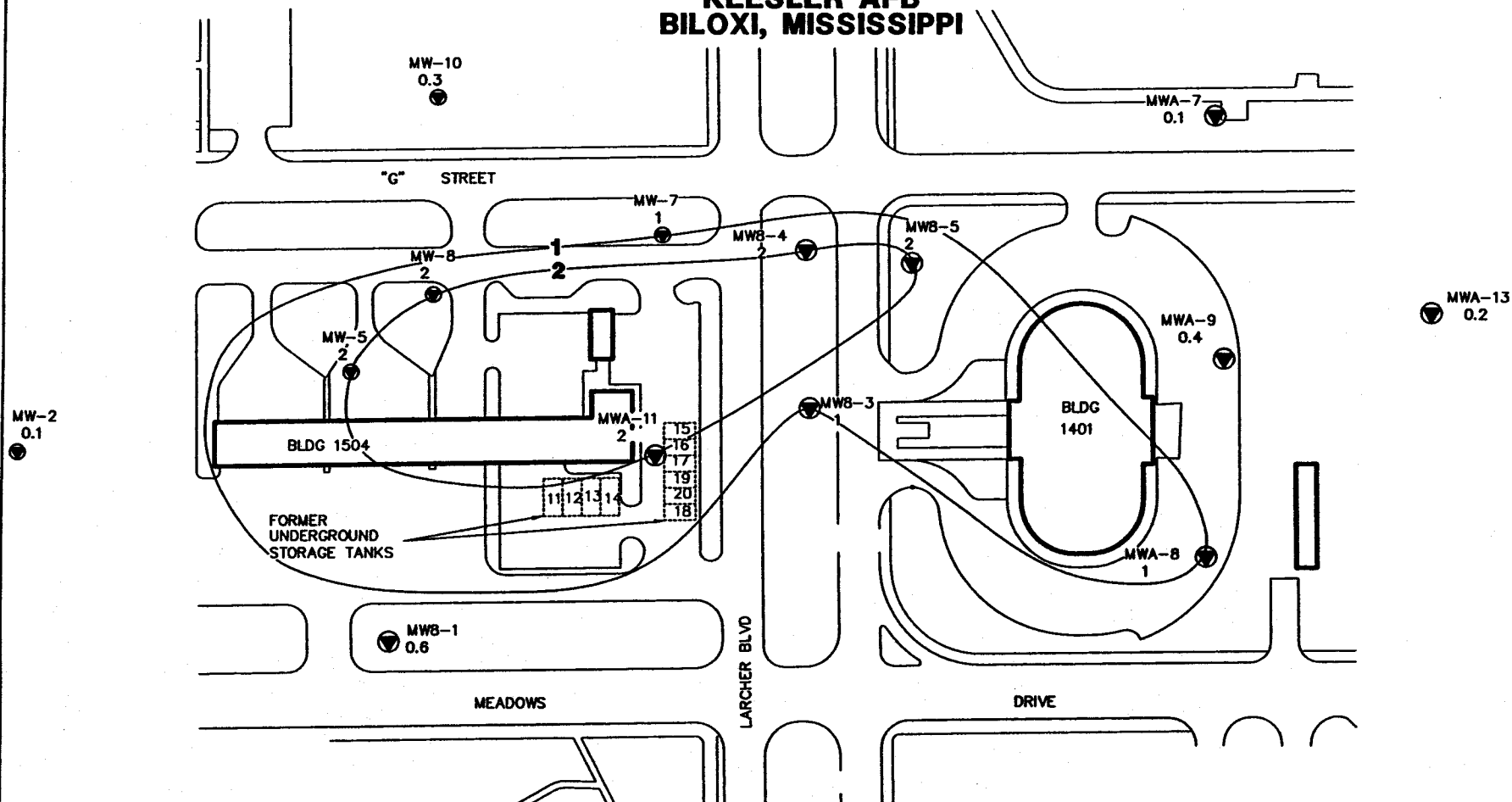
LEGEND

- MONITORING WELL
- 141.7 OXIDATION REDUCTION POTENTIAL IN MILLIVOLTS
- * METER IMPROPERLY WORKING



SCALE

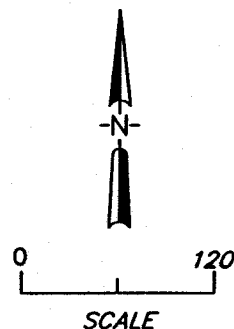
**FIGURE D.3
DISTRIBUTION OF AMMONIA-N IN GROUNDWATER
FACILITY 1504 AND AOC-A
KEESLER AFB
BILOXI, MISSISSIPPI**



KEY MAP

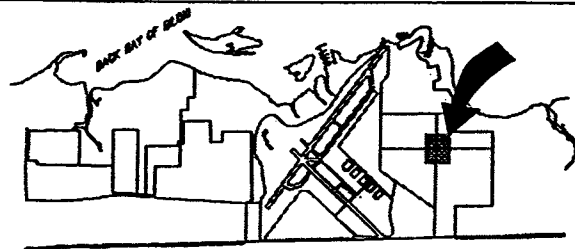
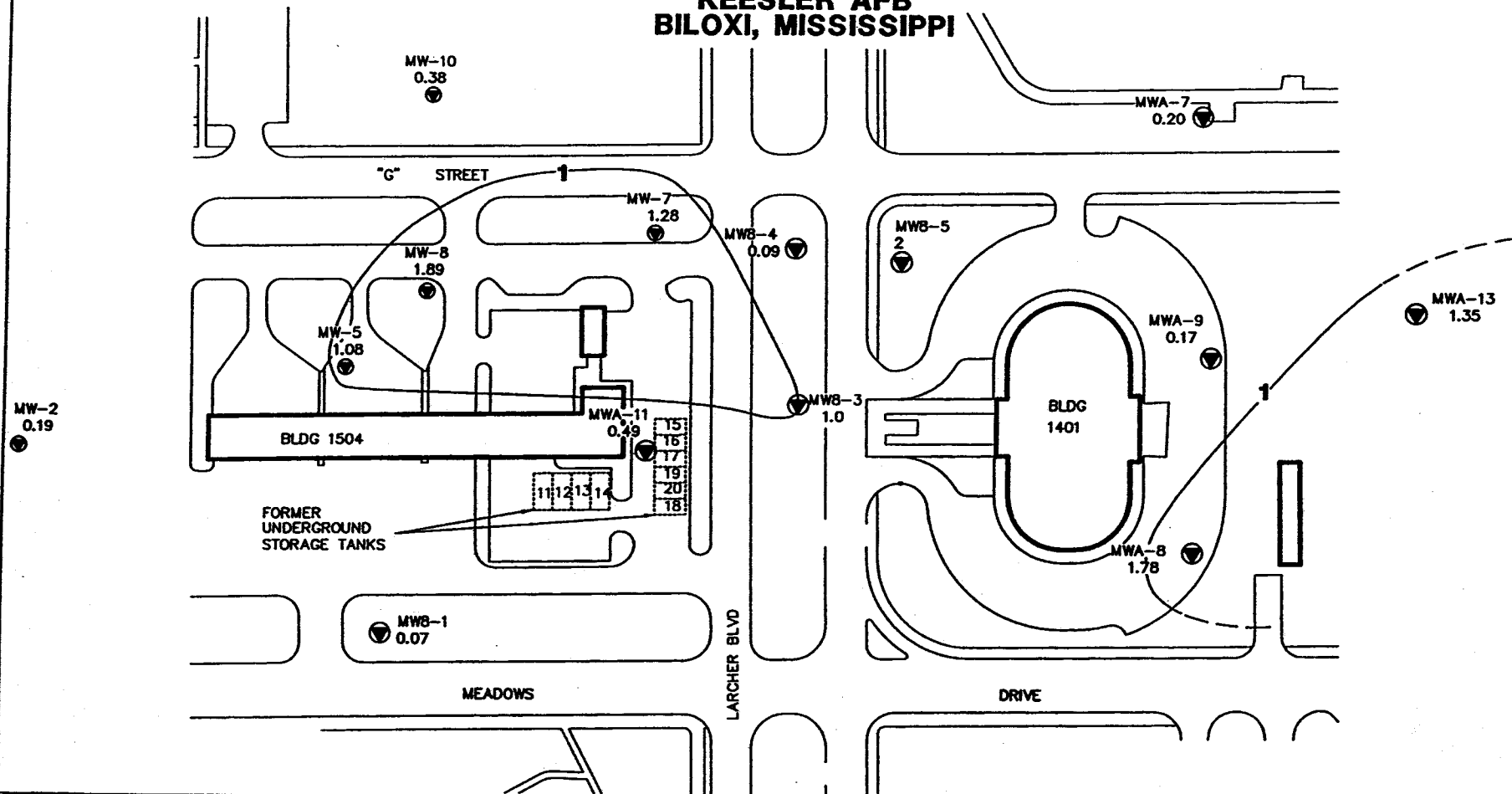
LEGEND

- MONITORING WELL
- 0.6 AMMONIA-N IN MILLIGRAMS PER LITER
- 2- LINE OF EQUAL AMMONIA-N



SCALE

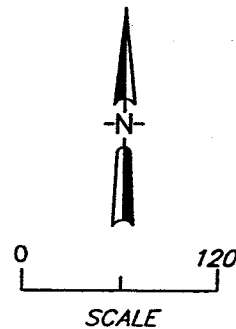
**FIGURE D.4
DISTRIBUTION OF FERROUS IRON IN GROUNDWATER
FACILITY 1504 AND AOC-A
KEESLER AFB
BILOXI, MISSISSIPPI**



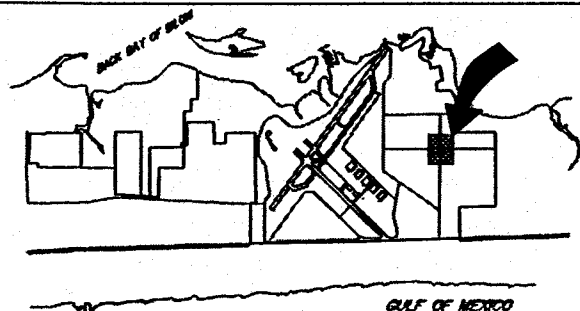
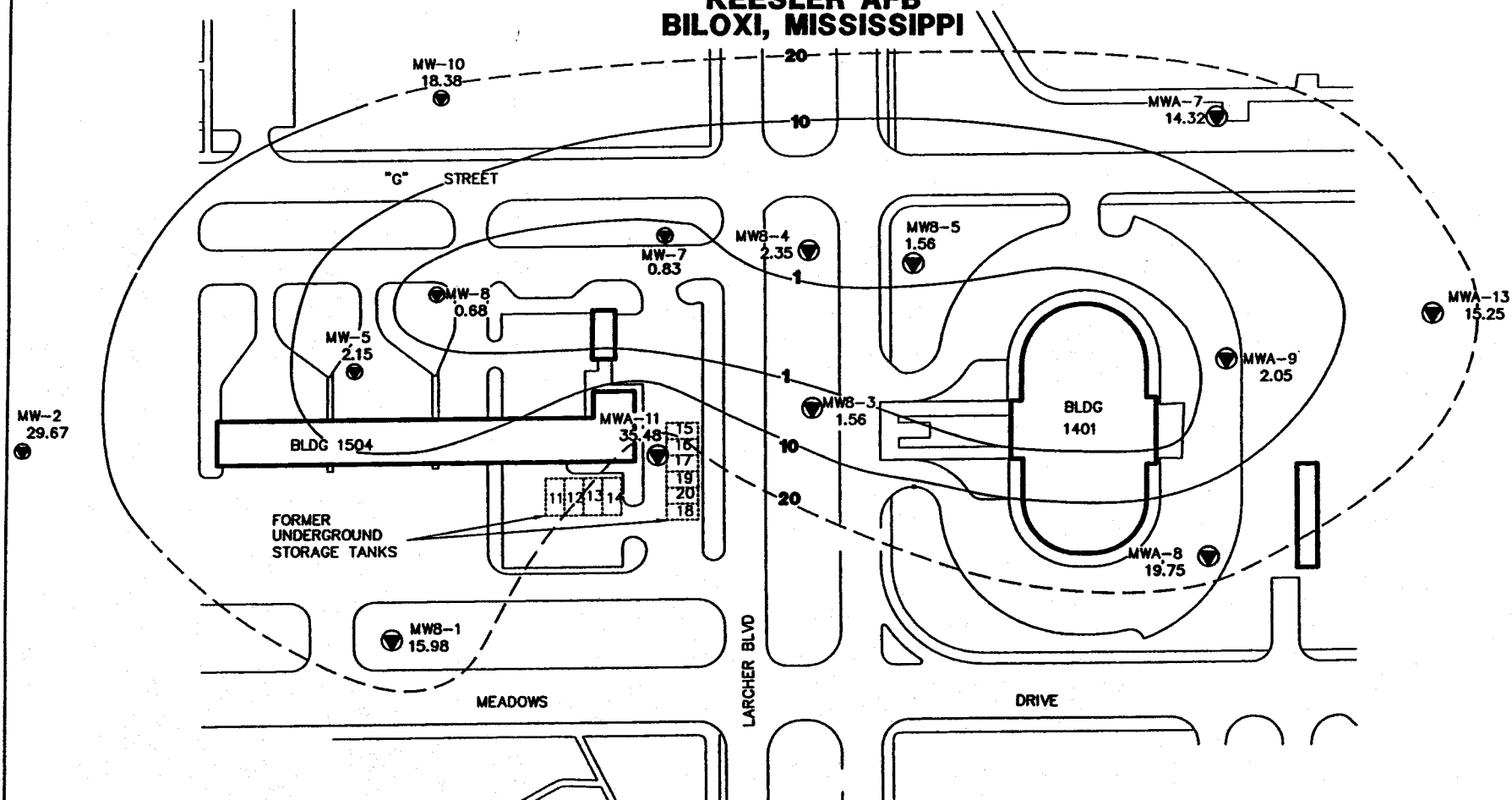
KEY MAP

LEGEND

- MONITORING WELL
- 1.28 FERROUS IRON IN MILLIGRAMS PER LITER
- LINE OF EQUAL FERROUS IRON DASHED WHERE INFERRED



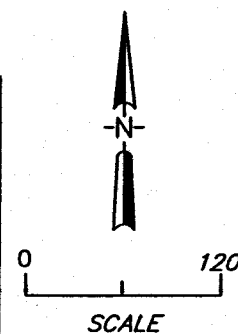
**FIGURE D.5
DISTRIBUTION OF SULFATE IN GROUNDWATER
FACILITY 1504 AND AOC-A
KEESLER AFB
BILOXI, MISSISSIPPI**



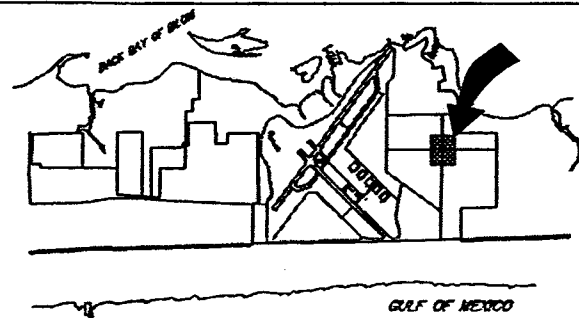
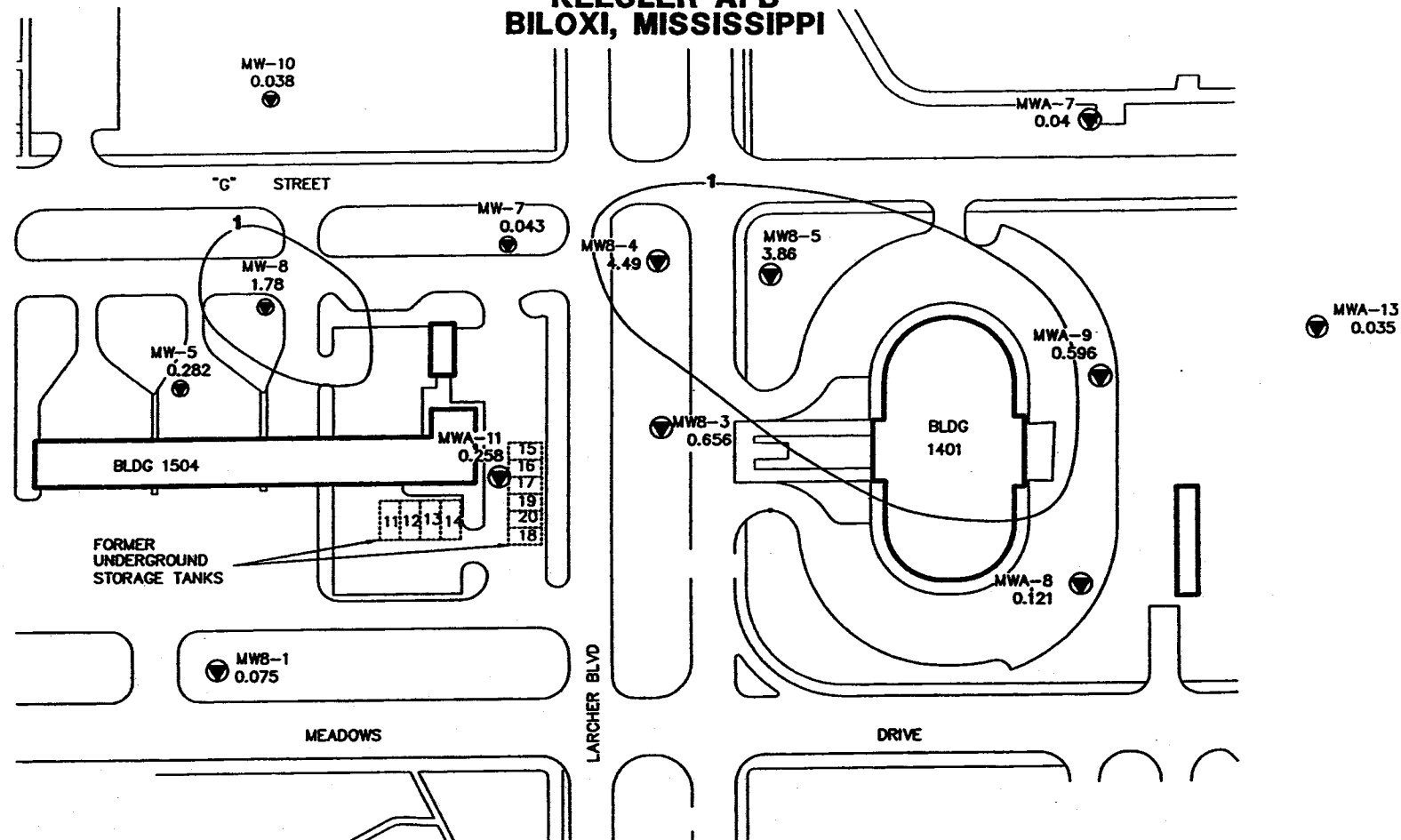
KEY MAP

LEGEND

- MONITORING WELL
- 35.48 Sulfate in MILLIGRAMS PER LITER
- LINE OF EQUAL SULFATE DASHED WHERE INFERRED



**FIGURE D.6
DISTRIBUTION OF METHANE IN GROUNDWATER
FACILITY 1504 AND AOC-A
KEESLER AFB
BILOXI, MISSISSIPPI**



LEGEND

- MONITORING WELL
- 4.49 METHANE IN MILLIGRAMS PER LITER
- - - LINE OF EQUAL METHANE DASHED WHERE INFERRED

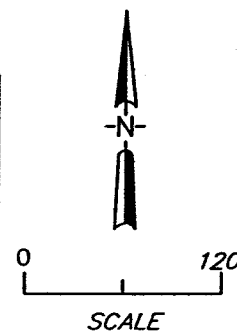


TABLE D.1
HISTORICAL COMPARISON OF GROUNDWATER ANALYTICAL RESULTS
Facility 1504
Keesler AFB
Biloxi, Mississippi

Location:	MW-2			MW-5		
Sample Date:	27-Apr-95	15-Sep-98	21-Jun-99	27-Apr-95	16-Sep-98	24-Jun-99
Benzene	BDL	< 1	< 1	880	315.6	282
Toluene	2.9	< 1	< 1	3.1	< 10	5.7
Ethylbenzene	BDL	< 1	< 1	82	22.4	24.6
Xylenes	BDL	< 1	< 1	12	< 10	65.5
Total BTEX	2.9	< 4	< 4	977.1	338	377.8

Location:	MW-7			MW-8		
Sample Date:	27-Apr-95	15-Sep-98	22-Jun-99	27-Apr-95	16-Sep-98	22-Jun-99
Benzene	4.6	< 1	126	15,000	1,989	3,220
Toluene	BDL	< 1	< 1.0	18,000	9,745	13,400
Ethylbenzene	BDL	1.2	< 1.0	2,500	931	940
Xylenes	BDL	1.3	< 1.0	13,200	2,798	6,200
Total BTEX	4.6	2.5	126	48,700	15,463	23,760

Location:	MW-10		
Sample Date:	27-Apr-95	15-Sep-98	21-Jun-99
Benzene	1.1	< 1	< 1
Toluene	2	< 1	< 1
Ethylbenzene	BDL	< 1	< 1
Xylenes	2	< 1	< 1
Total BTEX	5.1	< 4	< 4

1995 data from EA Report of Site Assessment Activities (1995)
 1998 data from Site Assessment Report: Facility 1504 (AAFES Service Station)
 BDL = below detection limit, detection limit not available
 Bolded results indicate detected compounds.
 Results are in µg/L.

TABLE D.2
HISTORICAL COMPARISON OF GROUNDWATER ANALYTICAL RESULTS
AOC-A
Keesler AFB
Biloxi, Mississippi

Location: Sample Date:	MW8-1			MW8-3			MW8-4		
	19-Nov-92	20-Feb-98	23-Jun-99	19-Nov-92	20-Feb-98	24-Jun-99	19-Nov-92	20-Feb-98	24-Jun-99
Benzene	< 1.0	< 2.0	< 1.0	6,000	2,500	520	< 1.0	880	489
Toluene	< 1.0	< 2.0	< 1.0	8,500	1,700	2,130	< 1.0	210	27
Ethylbenzene	< 1.0	< 2.0	< 1.0	1,400	10,000	234	8	89	54
Xylenes	< 1.0	< 2.0	< 1.0	5,800	8,200	810	4	600	163
Total BTEX	< 4.0	< 8.0	< 4.0	21,700	22,400	3,694	12	1,779	733

Location: Sample Date:	MW8-5			MWA-7		MWA-8	
	19-Nov-92	20-Feb-98	23-Jun-99	18-Nov-92	23-Jun-99	18-Nov-92	22-Jun-99
Benzene	63	1400	766	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	8	930	77	< 1.0	4.2	< 1.0	< 1.0
Ethylbenzene	31	< 100	840	< 1.0	< 1.0	< 1.0	< 1.0
Xylenes	170	530	1380	< 1.0	2.6	< 1.0	< 1.0
Total BTEX	272	2,860	3,063	< 4.0	6.8	< 4.0	< 4.0

Location: Sample Date:	MWA-9			MWA-11			MWA-13		
	18-Nov-92	19-Feb-98	22-Jun-99	20-Nov-92	19-Feb-98	24-Jun-99	20-Nov-92	19-Feb-98	22-Jun-99
Benzene	71	0.33J1	1.7	1,200	750	158	< 1.0	< 2.0	< 1.0
Toluene	4	7.7	1.1	1,100	250	98.4	< 1.0	< 2.0	5.9
Ethylbenzene	22	0.97J1	25.2	290	1,700	35.1	< 1.0	< 2.0	< 1.0
Xylenes	62	44	155	1,200	500	57	< 1.0	< 2.0	4.5
Total BTEX	159	53	183	3,790	3,200	349	< 4.0	< 8.0	10.4

1992 and 1998 data from RFI (April 1999)

BDL = below detection limit, detection limit not available

Bolded results indicate detected compounds.

Results are in µg/L.

J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.

TABLE D.3
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
Facility 1504 and AOC-A
Keesler AFB,
Biloxi, Mississippi

Coupled Benzene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor/Byproduct to Compound
$7.5\text{O}_2 + \text{C}_6\text{H}_6 \Rightarrow 6\text{CO}_{2,g} + 3\text{H}_2\text{O}$ <i>Benzene oxidation / aerobic respiration</i>	3.07:1
$6\text{NO}_3^- + 6\text{H}^+ + \text{C}_6\text{H}_6 \Rightarrow 6\text{CO}_{2,g} + 6\text{H}_2\text{O} + 3\text{N}_{2,g}$ <i>Benzene oxidation / denitrification</i>	4.77:1
$3.75\text{NO}_3^- + \text{C}_6\text{H}_6 + 7.5\text{H}^+ + 0.75\text{H}_2\text{O} \Rightarrow 6\text{CO}_2 + 3.75\text{NH}_4^+$ <i>Benzene oxidation / nitrate reduction</i>	2.98:1
$60\text{H}^+ + 30\text{Fe}(\text{OH})_{3,s} + \text{C}_6\text{H}_6 \Rightarrow 6\text{CO}_2 + 30\text{Fe}^{2+} + 78\text{H}_2\text{O}$ <i>Benzene oxidation / iron reduction</i>	21.5:1
$7.5\text{H}^+ + 3.75\text{SO}_4^{2-} + \text{C}_6\text{H}_6 \Rightarrow 6\text{CO}_{2,g} + 3.75\text{H}_2\text{S}^0 + 3\text{H}_2\text{O}$ <i>Benzene oxidation / sulfate reduction</i>	4.61:1
$5\text{N}_2 + \text{C}_6\text{H}_6 + 10\text{H}^+ + 12\text{H}_2\text{O} \Rightarrow 6\text{CO}_2 + 10\text{NH}_4^+$ <i>Benzene oxidation / nitrogen fixation</i>	2.31:1
$4.5\text{H}_2\text{O} + \text{C}_6\text{H}_6 \Rightarrow 2.25\text{CO}_{2,g} + 3.75\text{CH}_4$ <i>Benzene oxidation / methanogenesis</i>	0.77:1

Coupled Toluene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor/Byproduct to Compound
$9\text{O}_2 + \text{C}_6\text{H}_5\text{CH}_3 \Rightarrow 7\text{CO}_{2,g} + 4\text{H}_2\text{O}$ <i>Toluene oxidation / aerobic respiration</i>	3.13:1
$7.2\text{NO}_3^- + 7.2\text{H}^+ + \text{C}_6\text{H}_5\text{CH}_3 \Rightarrow 7\text{CO}_{2,g} + 7.6\text{H}_2\text{O} + 3.6\text{N}_{2,g}$ <i>Toluene oxidation / denitrification</i>	4.85:1
$4.5\text{NO}_3^- + 9\text{H}^+ + 0.5\text{H}_2\text{O} + \text{C}_6\text{H}_5\text{CH}_3 \Rightarrow 7\text{CO}_2 + 4.5\text{NH}_4^+$ <i>Toluene oxidation / nitrate reduction</i>	3.03:1
$72\text{H}^+ + 36\text{Fe}(\text{OH})_{3,s} + \text{C}_6\text{H}_5\text{CH}_3 \Rightarrow 7\text{CO}_2 + 36\text{Fe}^{2+} + 94\text{H}_2\text{O}$ <i>Toluene oxidation / iron reduction</i>	21.86:1
$9\text{H}^+ + 4.5\text{SO}_4^{2-} + \text{C}_6\text{H}_5\text{CH}_3 \Rightarrow 7\text{CO}_{2,g} + 4.5\text{H}_2\text{S}^0 + 4\text{H}_2\text{O}$ <i>Toluene oxidation / sulfate reduction</i>	4.7:1
$6\text{N}_2 + \text{C}_6\text{H}_5\text{CH}_3 + 12\text{H}^+ + 14\text{H}_2\text{O} \Rightarrow 7\text{CO}_2 + 12\text{NH}_4^+$ <i>Toluene oxidation / nitrogen fixation</i>	2.35:1
$5\text{H}_2\text{O} + \text{C}_6\text{H}_5\text{CH}_3 \Rightarrow 2.5\text{CO}_{2,g} + 4.5\text{CH}_4$ <i>Toluene oxidation / methanogenesis</i>	0.78:1

TABLE D.3 (CONTINUED)
COUPLED OXIDATION REACTIONS FOR BTEX COMPOUNDS
Facility 1504 and AOC-A
Keesler AFB,
Biloxi, Mississippi

Coupled Ethylbenzene Oxidation reactions	Stoichiometric Mass Ratio of Electron Acceptor/Byproduct to Compound
$10.5 O_2 + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,s} + 5 H_2O$ <i>Ethylbenzene oxidation / aerobic respiration</i>	3.17:1
$8.4 NO_3^- + 8.4 H^+ + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,s} + 9.2 H_2O + 4.2 N_{2,g}$ <i>Ethylbenzene oxidation / denitrification</i>	4.92:1
$5.25 NO_3^- + 10.5 H^+ + 0.25 H_2O + C_6H_5C_2H_5 \Rightarrow 8 CO_2 + 5.25 NH_4^+$ <i>Ethylbenzene oxidation / nitrate reduction</i>	3.07:1
$84 H^+ + 42 Fe(OH)_{3,s} + C_6H_5C_2H_5 \Rightarrow 8 CO_2 + 42 Fe^{2+} + 110 H_2O$ <i>Ethylbenzene oxidation / iron reduction</i>	22:1
$10.5 H^+ + 5.25 SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8 CO_{2,s} + 5.25 H_2S^o + 5 H_2O$ <i>Ethylbenzene oxidation / sulfate reduction</i>	4.75:1
$7 N_2 + C_6H_5C_2H_5 + 14 H^+ + 16 H_2O \Rightarrow 8 CO_2 + 14 NH_4^+$ <i>Ethylbenzene oxidation / nitrogen fixation</i>	2.38:1
$5.5 H_2O + C_6H_5C_2H_5 \Rightarrow 2.75 CO_{2,s} + 5.25 CH_4$ <i>Ethylbenzene oxidation / methanogenesis</i>	0.79:1

Coupled m-Xylene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor/Byproduct to Compound
$10.5 O_2 + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,s} + 5 H_2O$ <i>m-Xylene oxidation / aerobic respiration</i>	3.17:1
$8.4 NO_3^- + 8.4 H^+ + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,s} + 9.2 H_2O + 4.2 N_{2,g}$ <i>m-Xylene oxidation / denitrification</i>	4.92:1
$5.25 NO_3^- + 10.5 H^+ + 0.25 H_2O + C_6H_4(CH_3)_2 \Rightarrow 8 CO_2 + 5.25 NH_4^+$ <i>m-Xylene oxidation / nitrate reduction</i>	3.07:1
$84 H^+ + 42 Fe(OH)_{3,s} + C_6H_4(CH_3)_2 \Rightarrow 8 CO_2 + 42 Fe^{2+} + 110 H_2O$ <i>m-Xylene oxidation / iron reduction</i>	22:1
$10.5 H^+ + 5.25 SO_4^{2-} + C_6H_4(CH_3)_2 \Rightarrow 8 CO_{2,s} + 5.25 H_2S^o + 5 H_2O$ <i>m-Xylene oxidation / sulfate reduction</i>	4.75:1
$7 N_2 + C_6H_4(CH_3)_2 + 14 H^+ + 16 H_2O \Rightarrow 8 CO_2 + 14 NH_4^+$ <i>m-Xylene oxidation / nitrogen fixation</i>	2.38:1
$5.5 H_2O + C_6H_4(CH_3)_2 \Rightarrow 2.75 CO_{2,s} + 5.25 CH_4$ <i>m-Xylene oxidation / methanogenesis</i>	0.79:1

TABLE D.4
SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
Facility 1504
Keesler AFB
Biloxi, Mississippi

Analyte	Units	MW-2 21-Jun-99	MW-5 24-Jun-99	MW-7 22-Jun-99	MW-8 22-Jun-99	MW-10 21-Jun-99
Ferrous Iron	mg/L	0.19	1.08	1.28	1.89	0.38
Sulfate	mg/L	29.67	2.15	0.83	0.68	18.38
Ammonia-N	mg/L	0.1	2	1	2	0.3
Methane	mg/L	< 0.026	0.282	0.043	1.78	0.038
Temperature	Deg C	28.6	27.4	26.4	25.8	24.1
pH	SU	5.80	5.66	5.87	5.82	5.81
Conductivity	µS/cm	178	216	282	281	237
Dissolved Oxygen	mg/L	0.02	0.00	0.04	0.04	0.02
ORP	mV	81*	-112.9	64*	68*	85*

Methane analysis performed by Specialized Assays, Inc of Nashville, TN; all other analyses performed in the field

U = The analyte was analyzed for and is not present above the reporting limit

ORP = oxidation reduction potential

mg/L = milligrams per Liter µS/cm = microsiemen per centimeter

Deg C = degrees Celcius mV = millivolt

SU = Standard Units

* = ORP meter was working incorrectly. New meter received on June 23, 1999.

TABLE D.5
SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
AOC-A
Keesler AFB
Biloxi, Mississippi

		Sample Location and Date								
		MW8-1 23-Jun-99	MW8-3 24-Jun-99	MW8-4 24-Jun-99	MW8-5 23-Jun-99	MWA-7 22-Jun-99	MWA-8 22-Jun-99	MWA-9 22-Jun-99	MWA-11 24-Jun-99	MWA-13 22-Jun-99
Analyte	Units									
Ferrous Iron	mg/L	0.07	1.00	0.09	0.18	0.20	1.78	0.17	0.49	1.35
Sulfate	mg/L	15.98	1.56	2.35	1.56	14.32	19.75	2.05	35.48	15.25
Ammonia-N	mg/L	0.6	1	2	2	0.1	1	0.4	2	0.2
Methane	mg/L	0.075	0.656	4.49	3.86	0.04	0.121	0.596	0.258	0.035
Temperature	Deg C	25.2	25.0	24.4	24.7	22.9	26.9	26.4	27.8	24.1
pH	SU	5.63	6.38	6.26	5.58	5.91	4.77	5.76	6.18	5.69
Conductivity	µS/cm	254	498	313	147	263	118	175	285	164
Dissolved Oxygen	mg/L	0.01	0.03	0.03	0.02	0.18	0.08	0.00	0.00	0.00
ORP	mV	-110.0	-141.7	-165.8	-189.2	71*	138*	72*	-162.1	91*

Methane analysis performed by Specialized Assays, Inc of Nashville, TN; all other analyses performed in the field

U = The analyte was analyzed for and is not present above the reporting limit

ORP = oxidation reduction potential

mg/L = milligrams per Liter

µS/cm = microsiemen per centimeter

Deg C = degrees Celcius

mV = millivolt

SU = Standard Units

* = ORP meter was working incorrectly. New meter received on June 23, 1999.

TABLE D.6
ESTIMATED ASSIMILATIVE CAPACITY OF
SATURATED SOIL AND GROUNDWATER
Facility 1504 and AOC-A
Keesler AFB
Biloxi, Mississippi

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L) ^{b/}	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity ^{a/} (mg/L)	Benzene Assimilative Capacity ^{a/} (mg/L)	Toluene Assimilative Capacity ^{a/} (mg/L)	Ethylbenzene Assimilative Capacity ^{a/} (mg/L)	Xylenes Assimilative Capacity ^{a/} (mg/L)
Oxygen	NA ^{c/}	NA	NA	NA	NA	NA	NA
Ferrous Iron	NA	1.89	0.09	0.09	0.09	0.09	0.09
Sulfate	29.67	0.68	6.16	6.29	6.17	6.10	6.10
Ammonia ^{d/}	0.13	2.58	1.04	1.06	1.04	1.03	1.03
Methane	NA	4.49	5.74	5.83	5.76	5.68	5.68
Total			13.03	13.27	13.05	12.90	12.90
Max. 1999 Concentration			23.76				

^{a/} Calculation based on the ratio of the total mass of electron acceptor required to oxidize a given mass of the BTEX constituent

^{b/} mg/L = milligrams per liter

^{c/} NA = not applicable

^{d/} Concentration of ammonia = concentration of ammonia reported as N x 1.29 to convert to ammonia as NH₄